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PHYTOPATHOLOGY

VOLUME XIII NUMBER 5

MAY, 1923

STUDIES ON THE BLIGHT OF CUCURBITS CAUSED BY MACROSPORIUM CUCUMERINUM E. & E.

HAROLD ROY BRISLEY[1]

WITH THREE FIGURES IN THE TEXT

A leaf blight of cucurbits, caused by *Macrosporium cucumerinum* E. & E. is of great economic importance in the sections of Arizona where cucurbits are grown for commercial purposes. The disease has progressed so rapidly from year to year that during 1921 the crops of cantaloupes and watermelons were almost a complete failure in some sections. The failure was largely due to the leaf blight, although such other diseases as anthracnose (*Colletotrichum lagenarium* (Pers.) E. & H.) and a bacterial wilt were present.

SYMPTOMS

The disease usually starts about the middle of the growing season. The first noticeable evidence of it is a tan colored spot the size of a pin head formed when the organism has invaded the leaf tissue of the host. These minute spots enlarge and merge together, ultimately killing the leaf. With the leaves thus affected, a field of melons appears as shown in figure 1. The enlarged spots are made up of concentric, darker rings, always with a small, tan spot at the center. The central spot marks the point of infection, and is characteristic of the blight. The color of the spots varies according to the host, being light brown on cantaloupe and dark brown or almost black on watermelon, but the infection point at the center remains quite constant in color. When the over-ripe fruit is allowed to remain in the field, sunken spots from one-fourth to one inch in diameter appear which later become covered with a dark olive green growth of spores. During several seasons of observations over an extensive area the writer has never seen infections on the stems

[1] Studies here reported are an abridgment of work submitted at the University of California as a thesis for the Master's degree in Plant Pathology in 1922. Acknowledgment is due to Professor W. T. Horne, under whose direction the work was done, for helpful suggestions and criticisms.

or roots, nor on melons growing on diseased vines until the fruit has become over-ripe.

PATHOGENICITY

The organism was readily isolated on prune agar poured plates. The disease was reproduced on squash and cucumber leaves by a series of sixteen inoculations. These were made both by needle pricks and by placing spore-contaminated water on the unbroken leaf surfaces. With a single exception all of the inoculations on the leaves were successful while not a single infection was produced on the stems. The spores produced on one of the diseased leaves were used for making pure

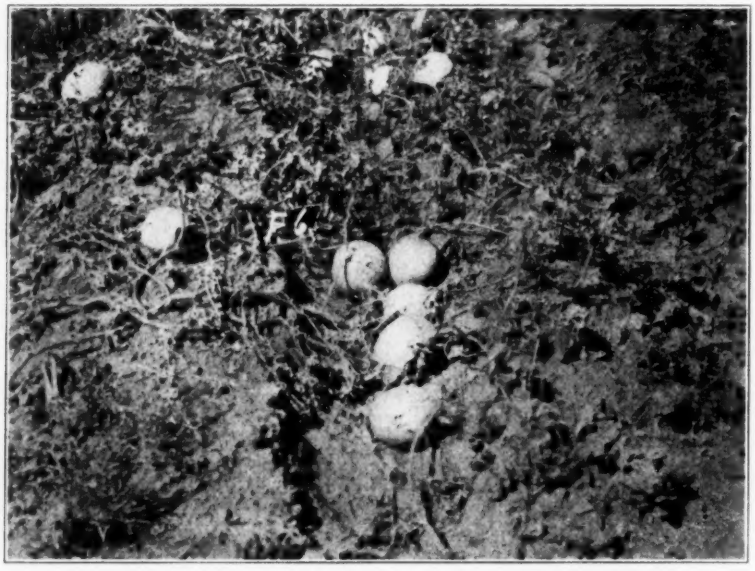

FIG. 1. Leaf blight on cantaloupes.

culture reisolations. One strain was the material employed in making 106 inoculations on cucurbits and 52 on other plants. This large number was made in order to demonstrate the pathogenicity of the organism. Ninety-six per cent of the cantaloupe inoculations, ninety-five of the squash, ninety-two of the watermelon, seventy of the cucumber, fifty of the potato and forty of the tomato were successful. Figure 2 shows infections produced by inoculations on the unbroken surface of a squash and a watermelon leaf. All of the inoculations made on the stems, petioles and roots were unsuccessful.

HOST RANGE AND RELATIVE SUSCEPTIBILITY

Experiments were made with ten different host plants (representing five different families), and it was found that they could be arranged in the following order in respect to susceptibility: cantaloupe, squash, watermelon, cucumber, potato and tomato. Those upon which the organism did not produce blight spots were turnip, cabbage, bean and orange. The growth of blight spots on all of the cucurbits was good, the inoculation period ranging from three to twelve days. It was very slow and uncertain in the cases of the potato and tomato, the period ranging from twelve to fifteen days.

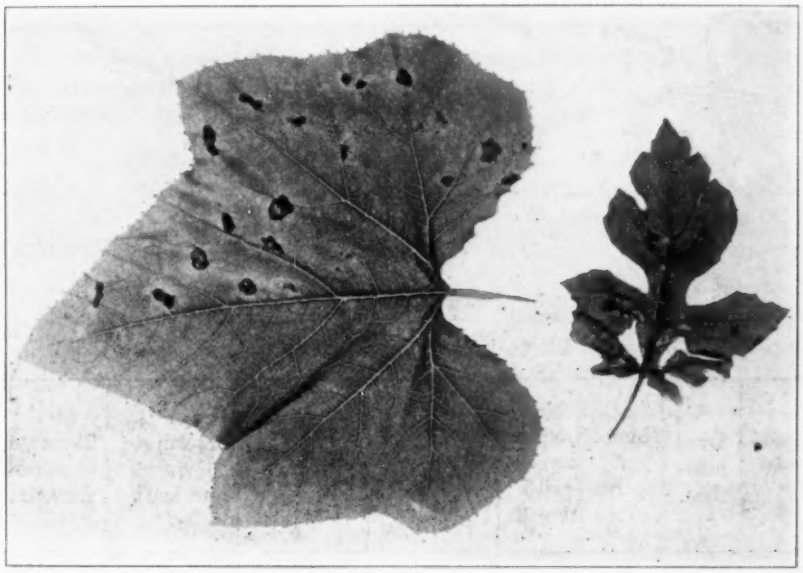

FIG. 2. Cantaloupe leaf-blight from inoculation.

CHARACTERISTICS OF THE FUNGUS

Some cultural characters. The organism will grow on any ordinary culture medium, though it grows best and most rapidly on prune agar. In an alkaline or a neutral medium the growth is slow, but when the medium is slightly acid it makes fast progress. The colony is most easily recognizable when grown on gelatin which is liquified at the center of the colony in twelve days. The growth on nutrient agar is also striking as the strands of mycelium cling together to form radiating cords which branch at relatively long intervals. On culture media the colony

is most often of an olivacious color, which is produced by the mycelial threads and spores. The former grow through the media while the latter are produced on the surface. Many colonies have a large amount of aerial mycelium which appears in cottony masses above the media.

Overwintering of the fungus. Studies described below indicate that the spores of *Macrosporium cucumerinum* do not carry the disease over the winter. This function is achieved by the mycelium which is capable of living over in the dried tissue. The conclusion reached from the

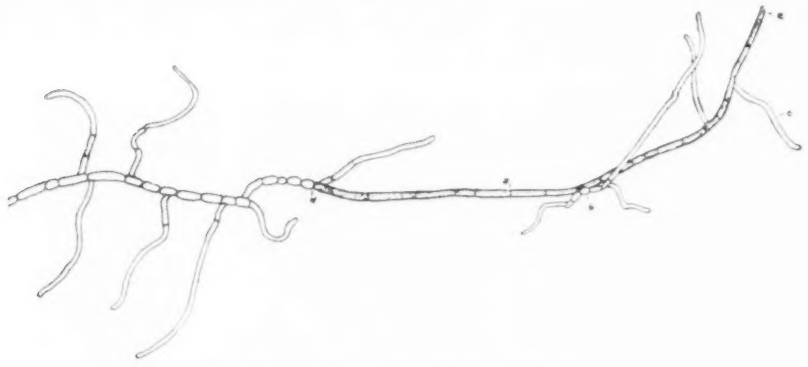

FIG. 3. Dried mycelium germinating.

TABLE 1—*Tabulated results of desiccation.*

Date	Drop number	Number of spores	Number of mycelial threads	Spores germinating after 24 hours	Mycelium germinating after 24 hours	Percentage of spores germinating	Percentage of mycelium germinating
Feb. 1	1	41	7	37	7	90	100
	2	18	10	17	9	94	90
	3	38	5	35	5	92	100
Feb. 10	1	28	4	12	4	43	100
	2	19	2	8	2	42	100
	3	35	6	20	5	57	83
Mar. 17	1	21	4	2	4	9	100
	2	35	6	3	5	8	83
	3	80	5	4	5	5	100
Apr. 10	1	20	5	0	4	none	80
	2	46	3	1	3	2	100
	3	18	8	0	7	none	87

study thus far is that the only function of the spores is that of dissemination during the growing season. After remaining dry for a few weeks the spores rapidly lose their vitality, while mycelium kept perfectly dry for nine months will readily germinate as shown in figure 3. This was concluded to be the fact only after many trials which yielded the same results. No samples of the diseased leaves now on hand have been kept for a longer period than nine months, so it is impossible to say for how long the mycelium will keep its viability.

The experiments regarding the viability of the spores and mycelium were conducted as follows. A culture of the organism growing on prune

TABLE 2—*Growth in millimeters at various temperatures.*

Tube number	Constant temperature ° C.	Diameter of growth at first	Diameter of growth after 4 days	Diameter of growth after 9 days	Diameter of growth after 15 days	Spore production after 15 days	Remarks
1	60	8	8	8	8	none	Organism killed
2	45	7	7	7	8	"	Growth very slight if any.
3	27	0	35	75	—	excellent	
4	21	0	24	55	80	good	
5	18	0	15	32	49	good	
6	11–15	4	6	10	15	fair	
7	10	4	5	7	10	poor	
8	3	4	4	4	4	few	The only evidence of growth was spores at center of colony
9	0	4	4	4	4	none	
10	—2	4	5	5	5	none	
11	—10	4	4	4	4	none	Medium frozen.

agar was evaporated to dryness in an incubator at a temperature of 33° C. When the culture seemed perfectly dry, three large hanging drops of spores and mycelium were made using prune agar as a medium. The following day by means of a mechanical stage the writer made a systematic count of spores and mycelial threads present in the drops, noting whether or not they were germinating. All groups where the mycelium was on top of or connected with the spores, all broken spores,

and all pieces of mycelium shorter than the length of a spore were disregarded. This was possible because of the large size of the spores. The above procedure was repeated ten days later with the same dried culture as a source of material, and again repeated in each of the two following months. The table above shows the results obtained. It will be noted that after ten days of drying a good percentage of the spores still retained their viability, but after three months practically none are capable of germination. However, in the case of the mycelial threads the percentage of germination after three months of drying is almost as high as it was after ten days. This demonstrates the fact that the mycelium will carry the disease over the winter while the spores are practically useless in this respect.

TEMPERATURE RELATIONS

The preceding table shows eleven different temperatures at which the growth of the organism was measured. The medium used was carrot agar. All of the cultures with the exceptions of numbers 3, 4 and 5, were kept at 21° C. for three days so that the colony had attained a diameter of 4 to 8 mm. before it was subjected to the temperatures indicated. Each was allowed to remain at a given temperature for fifteen days and the growth noted from time to time. It will be noted that the minimum temperature for growth was found to be about 3° C., the maximum about 45° C., and the optimum 30° C.

A MISLEADING SAPROPHYTE

A saprophytic Alternaria, which occurs on the diseased leaves with the Macrosporium, was introduced into the study because as a result of superficial examinations it has been considered and in some cases cited as being the cause of the blight. Through a series of inoculations it was proved beyond reasonable doubt that the only action of this organism is a saprophytic one. It does not grow in living tissue and does exceedingly well on dead leaves. The relation of this organism to temperature shows a much greater range than does the Macrosporium, demonstrating that it will withstand more unfavorable conditions than will the parasite.

A FUSARIUM WILT OF SPINACH

CHAS. W. HUNGERFORD

WITH FOUR FIGURES IN THE TEXT

During the summer of 1919 a disease of spinach was noted in several gardens in Moscow, Idaho, and in two other places in the state.[1] Since no report of the disease can be found in literature, a brief note of its occurrence is made at this time.

The first signs of the disease appeared when the plants were quite small. Here and there one was noted which was noticeably lighter colored than the rest and whose outer leaves were rolled inward at the margin and in more advanced stages were beginning to wither and die.

FIG. 1. Spinach plants growing in sterilized soil to which had been added a culture of *Fusarium spinaciae* when the seed was planted.

The leaves of the entire plant soon developed the same appearance and in about ten days these plants were entirely dead. Other plants soon developed this same condition and in about three or four weeks time, in the gardens where the disease was severe, there were only a very few plants which had not succumbed to the disease.

Upon pulling any of the plants in the advanced stages of the disease it was found that they came out of the ground very easily due to the

[1]Dr. V. H. Young, Professor of Botany in the University of Idaho, first called the author's attention to the disease on spinach plants in his garden. Later it was also found in several other gardens in Moscow.

fact that the root system had been practically destroyed. Nearly all of the fibrous roots were rotted off and the main root itself was scarred and blackened. Upon splitting the crown and main root a marked vascular browning characteristic of certain wilt diseases was found.

When diseased roots were placed in a moist chamber a white fungous growth developed in spots over their surfaces. Upon examination this growth proved to be a species of Fusarium. The same fungus was isolated from the interior of diseased roots.

In the garden where the disease was first noted spinach had been planted in the same place two years in succession. Volunteer plants were numerous over this part of the garden during the spring of 1919 before the ground had been plowed. The disease was much more serious

FIG. 2. Spinach plants growing in sterilized soil as check.

in this garden than in any of the others where it was noted and although it is not known whether the disease was present the year before, it seems reasonable to suppose that it was and that the fungus overwintered either on these volunteer plants or in the soil.

Spinach seed of the variety known as Long Standing, which was the variety on which the disease was first noted, was planted in two flats of sterilized soil in the greenhouse. The soil in one of the flats was inoculated with a pure culture of the Fusarium which had been previously isolated from diseased spinach roots. This was done by mixing a culture of the Fusarium growing on steamed rice with the soil when the seed was planted. The other flat was left as a check. Very soon after the

plants began to emerge there was a very noticeable difference in the vigor of the plants in the two flats. Those in the inoculated flat were much slower in growth, lighter colored, and some of them soon developed the characteristic symptoms of the disease as it had been noted in the field.

Figure 1 shows plants grown in inoculated soil 24 days after planting. Figure 2 shows the uninoculated check at the same time. It will be noted that many of the plants in figure 1 were already dead and that none of them were as vigorous as those in figure 2. Figure 3 shows four

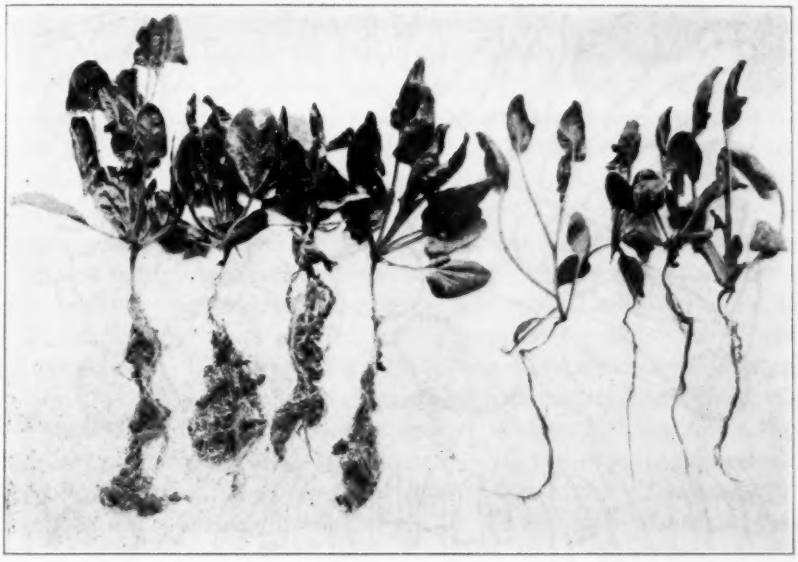

FIG. 3. Four spinach plants, on the left, taken from the check shown in figure 1 and four plants, on the right, grown in inoculated soil shown in figure 2.

healthy plants on the left taken at random from the check flat and four diseased plants, on the right, taken from the inoculated flat. The blackened areas on the surface of the roots of the diseased plants can be plainly seen.

The disease was found again in several gardens in 1920 and in 1921, but only a very few diseased plants were noted in any case. That the disease was so much more serious in 1919 may have been due to the fact that the season was exceedingly dry and the average soil temperatures were much higher than in 1920 when there was an unusually large amount of rainfall. During the summer of 1921 the disease was reported from

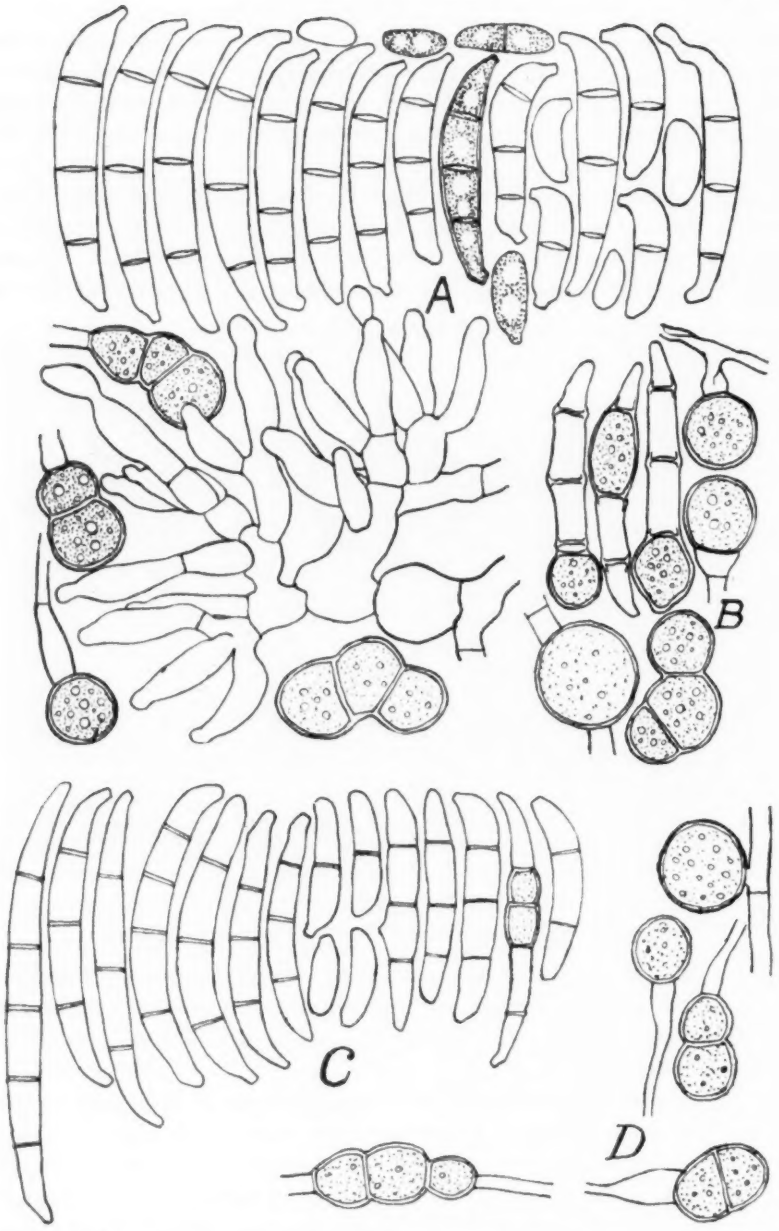

FIG. 4. A, "Normal" sporodochial conidia, a conidiophore and chlamydospores from 27-day old test-tube culture on potato-tuber plug with 5 cc. of 5% of malt extract; B, "old" sporodochial conidia with chlamydospores, and mycelial chlamydospores, from 8-months old test-tube culture on hard oat agar; C, "free" conidia and, D, mycelial chlamydospores from 9-day old Petri-dish potato agar. Magnification 1000 times.

Twin Falls County, which is in the irrigated region of southern Idaho. In 1922 it was reported from Lewiston and from Sandpoint. Specimens sent to the Experiment Station yielded what is apparently the same Fusarium that had previously been isolated.

As the Fusarium appeared to be different from any previously described a culture was sent for identification to Dr. C. D. Sherbakoff, Experiment Station, University of Tennessee, Knoxville, Tennessee. He considers it a new species and describes it as follows:

Fusarium spinaciae n. sp. (Fig. 4).—Conidia, when borne in sporodochia, are typically broader toward, and usually abruptly constricted at, the apex; pedicellate; mostly 3-septate, 5.25 × 35 (4.8–6.3 × 27–43) μ; 1-septate, 4.8 × 20 (4.4–5.0 × 14–24) μ; 0-septate, 3.2 × 8 (3.0–4.8 × 6–11) μ. Conidia, when borne singly on mycelium, are of a different type as shown in fig. 4, C. Chlamydospores mostly 0-septate, round and smooth, greatly varying in size, 11 (6–18) μ; 1-septate common, many-celled are also numerous in certain media. Aerial mycelium from short to medium height, fine; no sclerotia, no pionnotes; plectenchyma is sometimes produced in form of small flakes; small, whitish sporodochia were observed on some media. Color of mycelium on various media without addition of sugar is white; with addition of maltose it is usually light lilac; on rice, when seven weeks old, color of aerial mycelium is, by Ridgeway's Standard, from light seashell pink to pale-purple drab; the line of the medium and mycelium from dark, deep vinaceous and pinkish vinaceous to purple vinaceous, with only a slight diffusion of the color into the medium. In the type of sporodochial macroconidia the fungus is very closely related to *F. redolens* Wr.; macroconidia when borne singly are of a type intermediate between Fusaria of the Elegans and Martiella sections; the cell walls are usually thicker and the contents more granular than in most of the Fusaria of Elegans section, thus somewhat approaching Martiella section; on certain media, such as soy bean agar, chlamydospores are very numerous and very large as compared with other species of Elegans section and, in this way, the fungus can be readily distinguished from other Fusaria closely related to this species.

Hab. On roots of spinach, *Spinacia oleracea* Mill., Idaho, U. S. A.

DEPARTMENT OF PLANT PATHOLOGY,
UNIVERSITY OF IDAHO

OCCURRENCE OF BUNT IN RYE[1]

E. F. Gaines and F. J. Stevenson

With Two Figures in the Text

Bunt or stinking smut, *Tilletia tritici* (Bjerk.) Wint., is not confined to wheat, *Triticum sp.* but also attacks rye, *Secale cereale L.* In the literature referring to this parasitic fungus, it has been taken for granted, apparently, that it has but one host. Special mention is made of this fact by Sutton (3) and Humphrey and Potter (2), who state that bunt is limited to wheat as a host.

In the fall of 1921, one plant of common rye, one F_2 plant of a rye wheat hybrid, and two F_2 plants of a wheat-rye hybrid were found affected with smut, of which the fetid odor, and the size, shape, and roughened surface of the spores left no doubt that it was *T. tritici*. Figure 1 shows two bunted heads in comparison with a normal head of rye.

These hybrids were made at the Washington Agricultural Experiment Station with Rosen rye as one of the parents. As reported elsewhere (1), Rosen has been found peculiarly congenial in crossings with wheat, for fertile hybrids have been obtained when this rye was used as the female parent. Three such crosses have been made, Rosen × Hybrid 128, Rosen × Jones Fife, and Rosen × Jenkin, but every plant of the F_1, the F_2, and the F_3 generations has resembled rye, or the female parent, in its botanical characters. The wheat-rye hybrid, Turkey × Rosen, also resembled the female parent in the F_1, the F_2, and the F_3 generations, although it was different in many respects from Turkey. (Such hybrids in which the species of the pollen parent is not recovered in succeeding generations are rare, few ever having been cited, the best known in crosses with wheat being *Aegilops* × *Triticum vulgare*.) Bunted plants found in these hybrids, especially in Rosen × Hybrid 128, which was like rye in all its taxonomic characters, were thought to show genetic relationship with the wheat parent. To find bunt on rye, however, could have but one interpretation, namely, that rye is a host of *Tilletia tritici*.

To make a further test of this and to determine to what extent bunt infection of rye could be induced by artificial means, nine winter ryes

[1] This paper presents the results of investigations conducted cooperatively by the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, and the Washington Agricultural Experiment Station.

FIG. 1. First heads infected with bunt ever found on rye at the Washington Experiment Station, Pullman, Washington. Normal head in center.
Row 9001 A, Cereal Nursery, August 6, 1921. (× 1.)

and the F_2 generation of each of the four hybrids referred to above were sown under conditions favoring maximum infection. The seeds were blackened with spores of bunt obtained from smutted heads of several varieties of wheat and sown October 8, 1921, in a moist seed bed, thus insuring a combination of optimum conditions for infection. Fourteen spring ryes were treated in the same manner and sown April 29, 1922. The results of the 1922 harvest show that four out of the nine varieties of winter rye were made to act as hosts for bunt, although these four were relatively resistant to its attacks, while the other five apparently were immune.

TABLE 1—*Number of bunted and normal plants in rye and rye-wheat hybrids in comparison with those in wheat and wheat-rye hybirds*

Crop	Variety	Wash. No.	Sown in	No. of plants	
				Normal	Bunted
Rye	Utah	1741	autumn	55	5
"	Common	1738	"	61	1
"	German	1742	"	46	1
"	Yellow	995	"	35	0
"	Green	997	"	36	0
" (Parent)	Rosen	1940	"	100	0
Rye × Rye F_3	Spring × Minn. No. 2	999×991	"	14	2
" "	" " "	999×991	"	23	0
" "	" " "	999×991	spring	27	0
"	Spring	998	"	75	0
"	"	999	"	11	0
"	Mexican (S. P. I. 26102)	992	"	46	0
"	Dakold (C. I. 175)	996	"	57	0
"	Abbruzzes	994	"	57	0
"	C. I. 169	993	"	35	0
"	German	1742	"	38	0
"	Common	1738	"	60	0
"	Minn. No. 2	991	"	38	0
"	Yellow	995	"	46	0
"	A. Beardless	1086	"	48	1
"	Common	2349	"	17	0
"	Utah	1753	"	50	0
"	Rosen	1940	"	2	0
Rye × Wheat F_2	Rosen × Hybrid 128	1940×592	autumn	2008	68
" "	Roxen × Jones Fife	1940×371	"	503	3
" "	Rosen × Jenkin	1940×526	"	421	2
Wheat (Parent)	Turkey	326	"	42	25
" "	Hybrid 128	592	"	8	47
" "	Jenkin	526	"	3	10
" "	Jones Fife	371	"	3	24
Wheat × Rye F_2	Turkey × Rosen	326×1940	"	27	74

Table 1 gives the results of the infection experiments of 1922 on the winter and spring ryes and on the various rye-wheat and wheat-rye hybrids and their parents.

All plants that produced any smut balls at all were listed as bunted although some of them contained normal as well as bunted heads. The

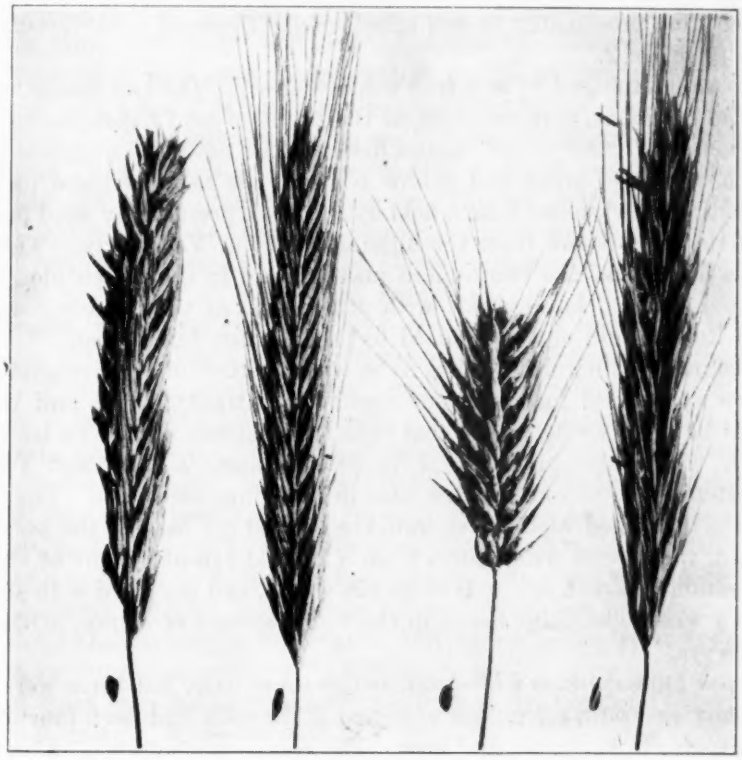

FIG. 2. A bunted and normal head of Yellow Rye (left) and of Rosen (right), found in the field plots, Washington Experiment Station, Pullman, Washington, in 1922. (× ½.)

F_3 of Turkey wheat × Rosen rye consisted of ten rows which showed infection with bunt ranging from 25 to 100 per cent. Thirty-eight of the seventy F_3 rows of the Rosen × Hybrid 128 family produced one or more affected plants while one row showed an infection of 10 per cent of bunted plants. Thirty-nine F_3 rows of Rosen rye × Jones Fife wheat were smut-free, but three others produced a total of eight bunted heads. In the other rye-wheat cross, Rosen × Jenkin, two of the 14 F_3 rows produced one infected plant each. The parents of these four crosses were sown as controls with the following results: Rosen rye was bunt

free, Turkey had 11 per cent, Hybrid 128 had 84 per cent, Jones Fife had 81 per cent, and Jenkin had 85 per cent of bunted heads.

The spring ryes were all bunt-free with the exception of Beardless which produced four bunted heads on one plant in a rod row containing 49 plants. Aside from these tests, three bunted plants were found in the field plots; one in a plot of Yellow rye and two in a similar plot of Rosen, due presumably to soil infestation. Types of each variety are seen in figure 2.

Rosen is supposed to be a true winter variety. The two plants which headed no doubt were mixtures or the result of field hybridization the previous year. One of the bunted Rosen plants produced a normal head which contained green and yellow seeds in the ratio of three to one, indicating that it came from a field hybrid seed, presumably wind pollinated the year before from the adjoining plot of Yellow rye. Thus it seems likely that the two bunted plants found in the Rosen plot were not pure Rosen, but hybrids with other ryes, as the nursery rows of pure Rosen could not be induced to produce any bunt at all.

The question naturally arises as to whether there may have appeared a new specialized form of bunt capable of attacking rye, and which might be more virulent on wheat than the common bunt. To test this point, three susceptible wheat varieties, Baart, Jenkin, and Pacific Bluestem, were chosen and the seed divided into three lots. The first lot was blackened with spores from the bunted rye head of the previous season, the second with spores from a bunted rye-like plant of the F_3 generation of Rosen rye $\times$ Hybrid 128 wheat, and the third with spores from a wheat-like plant found in the F_3 generation of Turkey wheat $\times$ Rosen rye.

A few bunted heads were produced in every case, but there were not as many as would have been expected if the seed had been inoculated with spores from the normal host. The results are shown in table 2.

TABLE 2—*Infection of susceptible spring wheats with bunt from spores obtained from different hosts.*

Host of Inoculum	Date seed was sown	Number of plants obtained					
		Baart		Jenkin		Pacific Bluestem	
		Normal	Bunted	Normal	Bunted	Normal	Bunted
Rye	May 4	60	7	50	6	57	6
Rye-Wheat	May 4	60	2	56	5	66	5
Wheat-rye	May 4	62	0	18	42	67	0
Wheat	April 29	10	47	8	79	12	72

The results obtained from seed inoculated with spores from wheat are not strictly comparable with the others, as the seeds were sown on April 29, while the others were sown on May 4, five days later. Earlier sowings usually produce more bunt, as wheat will germinate in a wider temperature range than will the smut spores.

Three varieties of spring rye also were inoculated with spores from these same four hosts, but no bunt appeared. Thus it appears that *Tilletia tritici* may pass one generation on rye as host, and still attack wheat feebly, but it is not shown to produce a second generation on rye.

From the description of *Tilletia secalis* (Cda.) Kuhn, given in Saccardo's Sylloge Fungorum, it seems possible that *T. tritici* and *T. secalis* are in reality the same fungus growing on different hosts. The rarity of "*T. secalis*" is in keeping with the great resistance of the rye varieties to *T. tritici* as determined in the above experiments.

The possibility of using bunt as an index of genetic relationships between wheat and rye in the rye-wheat hybrids is at once apparent. These hybrids, after the first generation, have all resembled the female parent to such an extent that they might be mistaken for pure-line ryes. This is true of the third generation families of Rosen × Hybrid 128, but the fact that they were quite susceptible to bunt as compared with the Rosen rye parent, which was bunt free in the control rows, indicates that they were true hybrids. Susceptibility to bunt, used as such an index, makes the work with hybrids of this nature much more significant than was formerly supposed, as it shows that something more than a stimulation has gone into the egg in the fertilization process. At least part of the chromatin material of the wheat pollen must be present, and functional in many of the F_2 segregates.

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STUDIES ON THE SO-CALLED BLACK HEART DISEASE OF THE APRICOT

HELEN CZARNECKI[1]

WITH PLATE XI AND FOUR FIGURES IN THE TEXT

A disease of the apricot manifesting itself by a sudden wilting of the foliage and discoloration of the wood has been under observation for several years.

In the spring of 1916, the writer became interested in the general group of diseases commonly termed "sour sap." During the months of March and April numerous cases of sour sap occurring on various stone fruits were observed, this being mainly a bark and cambium trouble, while in June a disease also included in this group, which affected the wood tissue only, was observed. These two marked differences led the writer to believe that the latter was a distinct type of disease and further study was made of this particular form.

DISTRIBUTION

The disease has been observed on the apricot in Alameda, Santa Clara, San Benito and Ventura Counties, and on the almond in Merced County. It has also been reported as occurring to a slight extent in Kings and Orange Counties. The disease is most commonly found in three to six-year-old trees which are heavily irrigated during the summer and inter-cropped with tomatoes. (Fig. 1.) It is not uncommon, however, to find the trouble both in younger and older trees. In several nurseries in Santa Clara County apricot seedlings and apricot and Myrobolan seedlings budded with apricot a month or so previous showed the disease. The distribution in the nursery was confined to certain blocks, while often adjoining blocks were healthy.

Many orchards of Alameda and Santa Clara Counties were visited. In Alameda County, in the young plantings of Centerville and Decoto apricot districts, the disease was observed in a large number of orchards; usually most of the trees were affected, although it was not uncommon to find only one or two affected trees to an orchard. A similar condition was found in the apricot orchards of Santa Clara County. For several

[1] This paper was prepared in 1917 by Miss Czarnecki, while a graduate student in Plant Pathology at the University of California. Publication has been unavoidably delayed until the present time. RALPH E. SMITH.

years Mr. E. L. Morris, formerly Horticultural Commissioner of Santa Clara County, had observed the disease in a large number of the orchards of his district. Mr. A. A. Brock, formerly Horticultural Commissioner of Ventura County, has reported that the disease has been observed in many of the younger apricot orchards throughout Ventura County. Mr. R. K. Bishop, formerly Horticultural Commissioner of Orange County, has observed it to a limited degree in Orange County. Mr. F. K. Howard reported that the disease had been quite common in Kings County for many years.

FIG. 1. Young apricot tree, typically affected with black heart.

THE DISEASE

The disease usually begins to show early in June. The leaves at the tip of one or more branches of a tree wilt and the wilting progresses rapidly downward until the entire branch is affected. The wilted leaves turn yellow and finally fall (Fig. 1). Previous to this time, so far as the writer has observed, no external symptoms of a diseased condition

can be detected. The foliage and fruit develop normally up to the time that wilting commences. Often those branches which become partly or wholly defoliated produce a pale yellow new growth later in the season. This wilting of one or more branches may continue until the dormant season. Upon cutting into a wilted branch the wood shows a brown to black stain (Pl. XI, A). The discoloration is often confined to one or

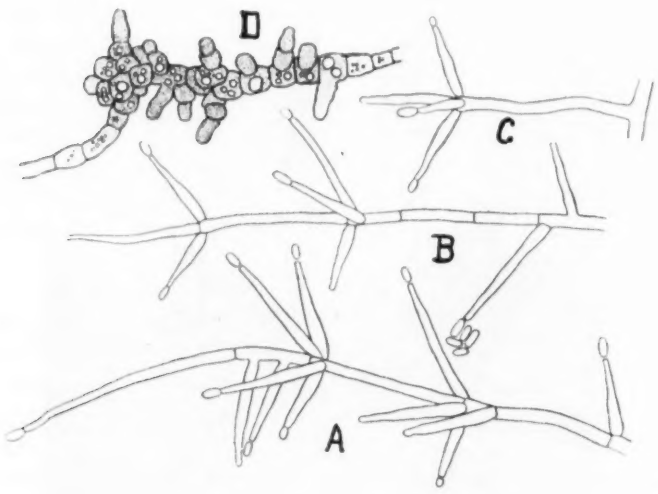

FIG. 2. Verticillium on standard nutrient agar. A, B, C—Verticillately branched conidiophores bearing single acrogenous conidia from 6-day-old nutrient agar culture. D. Aggregation of gemmae forming sclerotial mass, also from 6-day-old nutrient agar culture.

more annual rings and so, on cross-sectioning an affected branch, concentric black rings are observed. This discoloration was traced from affected branches into the main trunk and in no case was it possible to cut below the discolored area. However, the discoloration was less marked in the lower part of the trunk. Several dozen trees were examined, but in every case the discoloration was traced into the main trunk to the crown. The discoloration often extended into the main root, a few inches from the crown, but the laterals showed no darkening

of the tissues. These observations were made on two-year-old trees when the disease was fully developed for the season. These trees had the disease the previous season. Several horticultural commissioners, however, have reported that in cutting out wilted branches as soon as they appear, they have been able to cut below discolored wood. The sudden wilting of the branches is the mechanical effect of the formation of gum in the xylem vessels and the cutting off of the water supply of the tree.

In the literature of plant diseases, the only record which we have found of the occurrence of any similar disease is a disease of the plum in Georgia, called plum wilt. According to Higgins,[1] plum wilt is a destructive disease of the Japanese and hybrid varieties of plum in Georgia, North Carolina and Alabama. It manifests itself very similarly and is caused by a fungus of the genus Lasiodiplodia.

ISOLATION OF FUNGUS

On June 5, 1916, material was obtained from an affected apricot orchard at West San Jose, Santa Clara County. Frozen sections were made of affected branches, and the xylem vessels were seen to be filled with mycelium (Pl. XI, D). On June 7, cultures were made from this material. The branches were scrubbed and soaked in mercuric chloride (1–1000 in distilled water) for 15 minutes, rinsed in sterile distilled water, the outer bark peeled off with a scalpel sterilized in the flame and sections cut off the underlying tissue. Plantings were made on Shear's corn meal agar, standard nutrient agar, and in standard nutrient broth. Six cultures were made with each of the media.

On June 10, all six cultures on the corn meal agar showed an embedded fungus growth extending 1 to 3 mm. from the chip of wood. Five of the cultures on standard nutrient agar and four of the broth tubes showed a similar growth. After one month all six of the bouillon tubes showed a white pellicle on the surface and in the mycelium of the pellicle an abundance of small black sclerotial masses were produced. A moderate growth extended from the piece of twig at the bottom of the tube and an abundance of spores were produced which germinated in the liquid and produced a very characteristic flaky growth.

On June 14, eleven out of the twelve petri dish cultures which showed growth were transferred to nutrient agar slants. The original cultures were also kept and, with the exception of Pencillium contaminations, showed a pure culture of the fungus (Plate XI. C).

[1] Higgins, B. B., Plum wilt, Georgia Agric. Exp. Sta. Bull. 118, *29 p. illus.* 1916.

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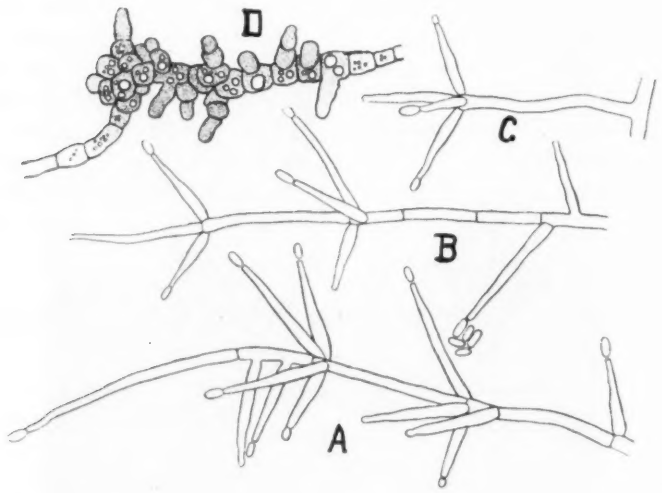

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Isolations were made from material collected at Berkeley, Oakland, Centerville and Decoto, Alameda County; Le Grand, Merced County; San Jose and Edenvale, Santa Clara County. One hundred and eighty two isolations, varying in number from 3 to 42 from each locality, yielded fungus growth in 137 instances.

All of the above isolations were made from 3 to 6 year-old apricot trees, with the exception of the material from Le Grand, Merced County, which were from two-year-old almond trees. The fungus was also isolated from imported Myrobolan seedlings, budded with apricot a month or so previous and also from seedling apricots budded with apricot.

HISTOLOGIC STUDIES OF AFFECTED TISSUE

A cross section of a badly discolored twig shows the cells of the bark and wood tissue to be filled with a mass of brown gum, especially the cells

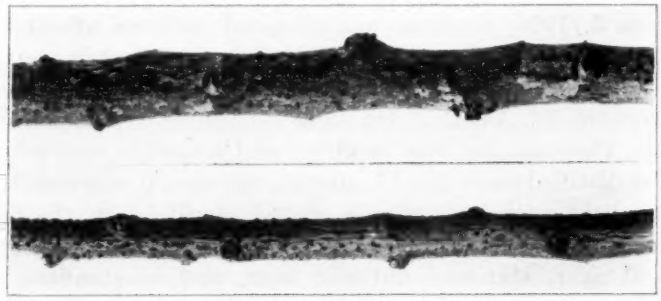


FIG. 2. Fruiting bodies on apical twigs affected with black heart.

of the medullary rays (Pl. XI, B). Either in frozen or paraffin sections, the fungus can readily be seen in the xylem vessels. In sectioning the tips of young growing branches 3 mm. in diameter, which show discoloration, many of the xylem cells show an abundance of the fungus mycelium, and the surrounding cells are filled with a brown, gummy, granular substance.

THE FUNGUS

The mycelium is uniform, septate, branched, 1.8–2.7 μ broad. Aerial upright verticillately branched conidiophores, 35–200 μ in length bearing conidia 6.75–11.25 × 2.25–6.75 μ at the apex of the branchlets, (Fig. 2), are produced in nutrient agar petri dish cultures after 6 days.

The spores germinate in dilute prune juice, producing tubes 3–45 μ

in length, 5–6.5 μ wide from either or both ends of the spore after 24 hours. In three days irregularly branched conidiophores begin to pinch off conidia. Often a solitary branch arising from the main mycelium produces spores from the tip. In 4–5 days the main mycelium divides and an abundance of gemmae are produced (Fig. 2, D).

CULTURAL STUDY OF THE FUNGUS

The cultural work up to the present time indicates that the fungus belongs to the genus Verticillium and is apparently a new species, as no previous record of a Verticillium of a true parasitic nature inhabiting

FIG. 4. Two-month-old culture of Verticillium on sweet potato, showing the compact aerial growth.

the sound wood tissue of the apricot, almond or any other fruit tree has been found.

In culture, the fungus produced a similar growth on all the media tried, which included standard nutrient broth, standard nutrient agar, potato, prune and corn agar, steamed rice, oatmeal, string bean pods and sweet potatoes. In the liquid nutrient broth an abundance of spores is produced from the piece of transplanted fungus. The spores germinate and produce a very characteristic flaky growth. In 7 to 8 days a pellicle is formed on the surface and in the mycelium of the

pellicle sclerotial masses are formed, which consist of an aggregation of dark vacuolate gemmae. In the agar cultures, which included standard nutrient, prune, corn, potato and oat agar, an even, embedded growth with a scant production of verticillately branched aerial conidiophores was produced within six days. After 10 days an abundance of the black aggregate masses of gemmae was produced irregularly throughout the embedded growth and on the surface of the medium. In media rich in starch, such as steamed rice, oatmeal, and sweet potato, an abundant compact aerial growth was produced (Fig. 4). As the cultures became older, black sclerotial masses formed in the mycelium and after several months the white mycelium flattened down and the sclerotial formation continued until a black crust was formed on the surface of the medium. In old cultures secondary white aerial tufts were produced.

TABLE 2—*The rate of growth and development of the fungus at the various temperatures.*

Culture No.	Temperature Degrees F.	Age of culture	Development
1–6 inc.	55	24 hrs.	Growth—1 mm.
7–12 "	64	24 "	Growth—2 mm.
13–18 "	73	24 "	Growth—2 mm. Production and germintaion of spores.
1–6 "	57	48 "	No increase in growth.
7–12 "	68	48 "	Growth 3 mm. Production and germination of spores.
13–18 "	75	48 "	Growth 5 mm. Increased production and germination of spores.
1–6 "	57	3 days	Growth 3 mm. Scant production and germination of spores
7–12 "	68	3 "	No increase in growth.
13–18 "	68	3 "	No increase in growth.
1–6 "	50	5 "	No increase in growth.
2–12 "	68	5 "	Growth 8 mm.
13–15 "	77	5 "	Sclerotia formed on side of flask.
16–18 "	99	5 "	No increase in growth.
1–6 "	50	10 "	No increase in growth.
7–12 "	68	10 "	Sclerotia formed on side of flask.
13–15 "	77	10 "	Pellicle formed on surface and an abundance of sclerotia.
16–18 "	98	10 "	No increase in growth.

FORMATION OF SCLEROTIA

In single spore dilute prune drop cultures, portions of the mycelium divide into short cells or gemmae. These cells broaden and become dark in color, and secondary gemmae are produced. In single spore cultures on standard nutrient agar, the gemmae multiplied until black sclerotial masses 50 to 250 μ in diameter were produced.

TEMPERATURE RELATIONS

After 10 days cultures in standard nutrient broth kept at 95° to 99° F. produced a scant growth in the liquid; at 68 to 77° F. a luxuriant growth in the liquid; a heavy pellicle on the surface and abundant sclerotia; at 64 to 68° F. a moderate growth in the liquid and a few sclerotia; at 50 to 57° F. a scant growth in the liquid.

INOCULATIONS

One set of inoculations was made in June, 1916, on a five-year-old seedling apricot. Twenty four one-year-old branches were selected, thoroughly washed with corrosive sublimate (1: 1000 in distilled water) and a flap was cut through the bark into the wood of each twig. A piece of fungus was placed under the flap of 12 twigs and the remaining 12 left as controls. All were tied with thread and covered with paraffin paper.

After one month, cultures were made from an inoculated branch as follows:

1–2 inc. 2″ from slit—wood discolored—contaminated by bacteria.

2–4 inc 4″ from slit—wood discolored—positive growth of Verticillium.

5–6 inc. 6″ from slit—wood discolored—positive growth of Verticillium.

7–8 inc. 8″ from slit—no discoloration—positive growth of Verticillium.

9–10 inc. 10″ from slit—no discoloration—no growth.

11–12 inc. 12″ from slit—no discoloration—no growth.

These results, together with the isolations of the fungus from black heart material from various sources as stated on page 8 corroborate the constant association of the fungus with this disease.

SOME LIGHT ON THE NATURAL MODE OF SPORE FORMATION

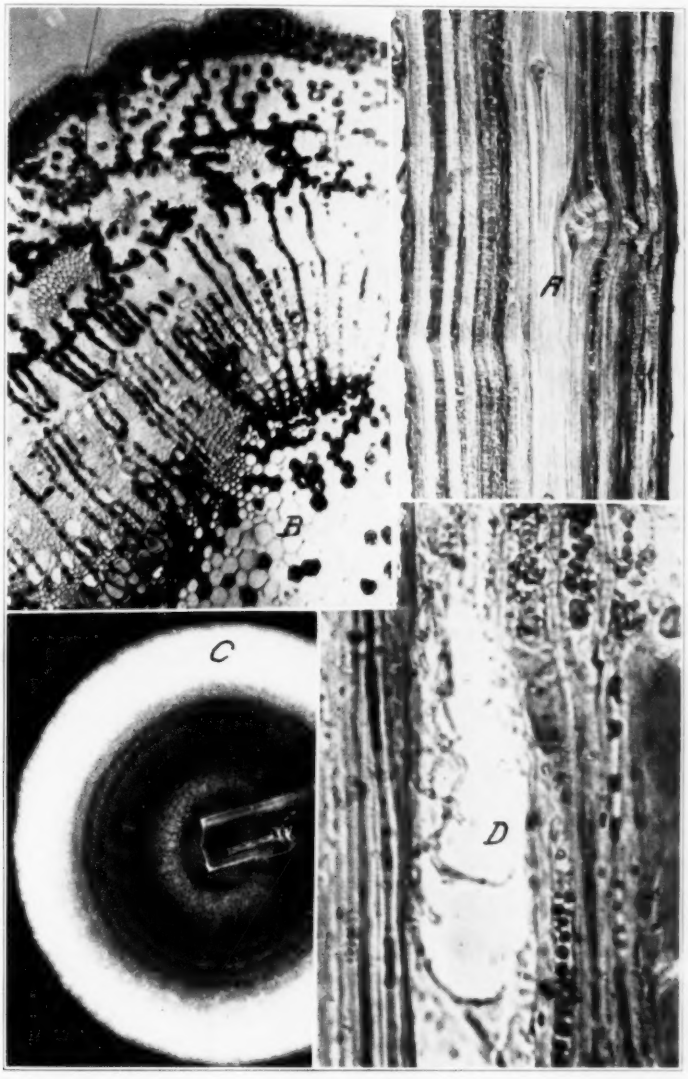
In January, 1916, it was observed that many of the affected trees showed numerous dead twigs, on the surface of which an abundance of black fruiting bodies 0.5 to 1 mm. in diameter had developed (Fig. 3).

Freehand and paraffin sections showed these bodies to be an aggregation of gemmae into a hard mass, a body similar if not identical with the sclerotial mass produced by the Verticillium in culture. No definite stroma or spore cavity was observed. These bodies were often covered with a greenish growth of Cladosporium. Every attempt to culture the fungus by sterilizing the surface of the twigs with corrosive sublimate and then planting the fruiting bodies on standard nutrient agar failed. An abundant growth of the Cladosporium and other saprophytes was obtained, but nothing suggestive of a Verticillium. Blackheart twigs were placed in water and kept in the open for several weeks and after a rain of several days, fruiting bodies which appeared free from the Cladosporium growth were found. From the gemmae on the surface of these black sclerotial masses, short solitary conidiophores, bearing conidia at the apex, were produced. Poured plates were made from these spores and a mixed growth of the Cladosporium and the typical Verticillium was obtained.

On June 6, 1916, small twigs showing typical black heart discoloration were cut into 4 inch lengths, soaked in mercuric chloride (1:1000 in distilled water) for 15 minutes, rinsed in sterile distilled water, the outer bark peeled off with a scalpel sterilized in the flame, and each placed in a test tube containing 5 cc. of sterilized distilled water. When the twigs were examined March 12, 1917, the surface was covered with sclerotial masses similar to those on the affected twigs obtained from the orchards.

PROBABLE CONTROL

The probable method of control will be tree surgery, by immediately cutting out wilted branches if it proves possible to cut below affected areas, or else by removing the entire tree in the fall, in order to prevent spore infection the following year from the fruiting bodies on the dead twigs of affected branches.



BLACK HEART OF APRICOT

A. Longitudinal section of affected branch showing characteristic discoloration. B. Cross section of small twig showing bark, wood and pith cells clogged with gum. C. Fungus after one month's growth on standard nutrient agar from chip of wood from apricot branch affected with black heart. D. Longitudinal section of small twig showing mycelium in the xylem vessels and granular gummy substance in the cells.

FUSICOCCUM CANKER ON APPLE

CHARLES CHUPP AND GRACE L. CLAPP

WITH PLATE XII

Young Duchess of Oldenburg apple trees were sent in February 1921 from a storage cellar at Newark, N. Y., to the State College of Agriculture for examination. Accompanying the specimens was a letter stating that about a hundred nursery trees of this variety were affected with black cankers at or near the bud union, and occasionally farther up the stem near the branches. None of the varieties making up the remainder of the stored stock were affected.

The specimens when examined showed black cankered areas 4 to 6 inches long, partly encircling the scion and frequently on the stock just below the graft insertion. The cankers were smooth externally, not depressed, and brown under the bark, the discoloration extending entirely through the sap wood (Pl. XII, fig. 5). Superficially the symptoms were somewhat the same as those caused by *Bacillus amylovorus*, particularly since no fungous fruit-bodies were present. Subsequently, it was learned that the causal organism seldom fruits until the host has been killed.

In cross section the discolored area is found to be filled with branched, septate, hyaline mycelium 1 to 2 μ in diameter. It is both inter- and intracellular. Minute stromata form immediately below the periderm of the host. These increase rapidly in size and soon show enclosed conidiophore layers near their centres. By this time the periderm has been pushed outward, and finally breaks, due to the mechanical pressure applied to it, thus permitting a portion of the stroma to protrude (Pl. XII, fig. 7). This opening or hole is at first a narrow slit, but gradually becomes circular. The protruding stromata are usually grouped very closely together and are quite small as compared with the pycnidia of a species of Cytospora which is rather common on weakened apple twigs, and which occasionally may be found on the same limb with the fruit-bodies described above (Pl. XII, fig. 6).

Isolations were made by planting in potato agar pieces of tissue taken at the line of demarcation between the healthy and diseased areas. Pure cultures of a rather slow growing fungus were easily obtained. Various types of media such as apple agar, cooked apple, sterilized apple twigs, oat agar and potato agar were used in the culture work.

The organism grew equally well on any of the media, so that for most of the later work, potato agar alone was employed. On this medium as well as on other agar concoctions, the fungus grows appressed to the surface. At first the mycelium is white but gradually changes to *courge green* (Ridgeway). In old cultures it is almost totally black with patches of white aerial mycelium. The growth is rather slow, taking 7 to 10 days to spread from the centre to the margin of a nine centimeter petri dish when the temperature is at the optimum.

After two to four months the surface of the cultures is marked with numerous tussock-like stromata (Pl. XII, fig. 4) in which are found the spore bearing cavities. The number of these cavities in each stroma varies from one to several. They are very irregular in outline, and differ much in size. The principal cavity ordinarily is ellipsoidal with one or two partly separated chambers branching from the main loculus. The cavities are lined with thin long, straight conidiophores arising from cells of the pseudoparenchymatous tissue.

Arising from similar cells and thickly interspersed among the conidiophores are thin, long, hyaline, variously curved, unicellular bodies, which in another species have been named scolecospores by Shear (7) and are generally referred to by European writers as pseudo-paraphyses (Pl. XII fig. 8). The latter term is probably the more desirable since they have never been induced to germinate. Furthermore, the prefix to the term would differentiate them from the true paraphyses present in ascomycetous fruit-bodies. The pseudo-paraphyses are deciduous, and not only are found emerging with the conidia, but are present in abundance after the conidia have all been discharged, and may then be seen exuding in a grayish slimy mass.

The conidia are hyaline, one-celled, and cylindrical with tapering ends. They show two very pronounced oil-droplets, which in darkly stained preparations have the appearance of cross walls. Singly they appear hyaline; in mass they are yellowish and discharged in long orange-colored tendrils. They germinate readily at room temperature in 24 hours.

The fungus in question is a Fusicoccum. Several of the species of this genus have been described as occurring on dead or living parts of fruit trees. Ellis and Everhart (2, p. 287) describe *F. persicae* on dead limbs of peach trees. Potebnia (4, p. 15) lists *F. pruni* on plum. Reddick (5) proved that *F. viticola* was the cause of the dead-arm disease of grapes, while three species have been found on apple, namely, *F. complanatum* Delacr. (1), *F. malorum* Oudem. (3, p. 529) and *F. microsporium*

Potebnia (4). This last species, as described by Potebnia, has a stroma like that of *F. complanatum*, but the spores are smaller than those of the latter fungus. Saccardo points out that Potebnia was working with immature specimens, and that during the following June spores 10 μ in length were produced. He, therefore, makes *F. microsporium* synonymous with *F. complanatum*. Other species have been found on widely different hosts.

Roberts (8) has described a fungus on apple, and following Diedicke's classification (9), has named it *Phomopsis mali*. As far as spore measurements are concerned it compares closely with the Fusicoccum. In other respects it is quite distinct. According to Roberts, "The globose rather large pycnidia of the fungus develop singly or in a raised stroma from one-half to one cm. across." The Fusicoccum pycnidium, on the other hand, is comparatively small, elliptical rather than globose, and no stromae have been found which measured even a thousand microns across. Furthermore, the cankers are perfectly smooth so that they never suggest a "rough-bark" condition, and leaf inoculations have not proved successful as were those reported by Roberts for Phomopsis (10).

As far as the gross morphological characters are concerned, the fungus on the Duchess nursery stock differs from all the described species with the possible exceptions of *F. viticola* Reddick and *F. malorum* Oudemans. For instance, in *F. complanatum*, of which type specimens from Delacroix's collections of 1890 and 1908 were kindly sent to the writers by Dr. E. Foëx of France, the spores differ from those of the fungus in question both in width and length, and the pseudo-paraphyses are unlike, being 4 to 5 μ in width, very long, branched, and multiseptate.

The description of *F. viticola* Reddick, on the other hand, fits the fungus very closely, and the possibility presents itself of the dead-arm organism also causing a canker on apple. Two different collections of dead-arm were obtained from the Chautauqua grape district and isolations made. The cultures on potato agar at first resemble very closely those that were obtained from apple, that is, the mycelium is closely appressed to the agar and, snowy white, but it grows much more slowly (Pl. XII, fig. 9) and does not turn to courge green or black. In addition when apple twigs on growing trees are inoculated, no canker results, although inoculations made with the apple fungus on the same trees give typical cankers in from three to four weeks. The inoculations are made by first washing the twig with a corrosive sublimate solution, and rinsing with sterilized water. A leaf petiole is then removed close to the twig with a flamed scalpel, a small amount of mycelium culture

applied, after which the lesion is wrapped in cotton which has been rinsed in sterilized water. The cotton is protected by lead foil wrapped over it. It has been found that the apple fungus will not produce infection unless the host is first injured. When the inoculum is applied over a cut leaf petiole, the results apparently are surer than when inoculations are made directly through the bark. In a similar manner inoculations were made on grape. The apple fungus did not cause dead-arm, while definite lesions were produced by *F. viticola*.

From the results of these reciprocal inoculations and reisolations together with the differences in cultural characters, such as color and manner of growth, it seems safe to conclude that the organisms on apple and on grape are two distinct species.

It is not so easy to prove that the apple fungus is different from species named by Oudemans as *Fusicoccum malorum*, and which he described as follows:

"Stromata wartlike, black, erumpent, of various forms, with very uneven surface, irregularly chambered, the chambers lined with straight, rather long sporophores. Spores spindle-shaped, hyaline, unicellular, smaller at each end, 7–9 $\mu \times 2$–3 μ."

Nothing at all is said regarding pseudo-paraphyses which are usually the most striking parts of the pycnidium. Furthermore, Oudemans' fungus was found on the apple fruit and not on the branches. This may be an important difference inasmuch as the Fusicoccum found on the nursery stock probably never causes a rot or spotting of the fruit under natural out-door conditions. It is true that the orgainsm will cause infection when artificial inoculations are made, but the progress of decay is so slow that even under optimum temperature and humidity it takes six weeks to get any appreciable amount of infection, and six months to decay the whole fruit, or to obtain spores for dissemination.

The description of *F. malorum* being so meagre, a request for type material was made. Dr. J. C. Schoute, director of the Gröningen Botanical Laboratory of the State University, Holland, kindly searched through the herbarium left by Dr. Oudemans, but could find no material under that name, or under any possible synonymous name. The lack of type material makes it impossible ever to compare the two organisms. Consequently, it is considered better to place the apple canker fungus under a new species and describe it as *Fusicoccum pyrorum* n. sp.

Fusicoccum pyrorum n. sp.

Stroma very pronounced, at first covered by the periderm of the host, later erumpent, enclosing one to several irregular plurilocular pycnidia,

horizontally ellipsoidal, from 300 to 500 μ × 450 to 900 μ. The cavities are lined with narrowly lanceolate, hyaline conidiophores approximately 15 μ × 1 μ. Interspersed among the conidiophores are thin, long, hyaline, variously curved, deciduous pseudo-paraphyses, 0.5 to 1.8 μ in width and 15 to 30 μ in length, averaging 1.2 × 23.4 μ. Conidia are one celled, cylindrical, bi-guttulate with tapering ends, and discharged in yellow tendrils. The conidia vary in length from 6 to 10 μ and in width from 1.5 μ to 3.5 μ averaging 2.5 × 7.5 μ.

Produces cankers on living branches and trunks of *Pyrus malus* L.

The ecological relationships of the parasite were not studied, but incidently a few observations were made. At first the cultures were placed in an incubator registering 27° C. At this high temperature, the mycelium grew very slowy, and fruit bodies were lacking entirely. When the temperature was reduced to 25° C. the mycelium grew luxuriantly, still no pycnidia were formed. All the cultures, however, when removed from the incubator and held at room temperature (18 to 21° C.) produced pycnidia abundantly.

The fungus is found on trees that first have been injured or weakened from some other cause. The Duchess of Oldenburg trees, on which the organism was first discovered had been placed in storage, and evidently were not in as vigorous condition as was the other stock in the same storage house. The same disease was found in Wayne County, N. Y., during the summer of 1922 on young Twenty Ounce trees that had been damaged by low temperatures during the previous winter. Specimens were received also from Picardy, Maryland, the twigs of the young trees having been injured severely by the Buffalo treehopper (*Ceresa bubalus* Fab.). Furthermore, the trees grown outdoors withstood infection to a much greater extent than did similar trees which had been transplanted into the greenhouse.

Ulster County, New York, and Suffolk County, Long Island, may be added to the places mentioned above where *Fusicoccum pyrorum* has been collected. Probably it is rather common but has been overlooked because of the other forms of the imperfect fungi found on the weakened or dying parts of the apple tree.

No attempts were made to apply control measures, but from the results of inoculation experiments, it would seem that the keeping of the trees in an actively growing condition, and free from injuries would be the two requirements necessary for keeping the fungus in check.

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DESCRIPTION OF PLATE XII

Fig. 1. Canker on branch showing discoloration of bark. The dead area is not depressed.

Fig. 2. Part of an infected twig, which had been placed in a moist chamber until the spores oozed in tendrils.

Fig. 3. Canker on young tree which had been inoculated with a pure culture. One infected twig was removed.

Fig. 4. Inoculated apple fruit, showing decay and stromata. The inoculations were made six weeks and nine months respectively, before photographing.

Fig. 5. Cross section of cankered branch showing depth of injury.

Fig. 6. Canker showing fruit bodies of Cytospora (the large, scattered projections on the left) and Fusicoccum (the smaller, more numerous ones on the right). The pycnidia of Cytospora are tipped with white, and come to a sharp point, while the pycnidia of Fusicoccum have rounded tops, and elongated slits.

Fig. 7. Cross section of pycnidium which is lined with conidiophores and pseudo-paraphyses.

Fig. 8. Photomicrograph of spores and pseudo-paraphyses.

Fig. 9. Cultures of *F. pyrorum* and *F. viticola* showing the more rapid growth of the former. Both cultures were prepared at the same time.

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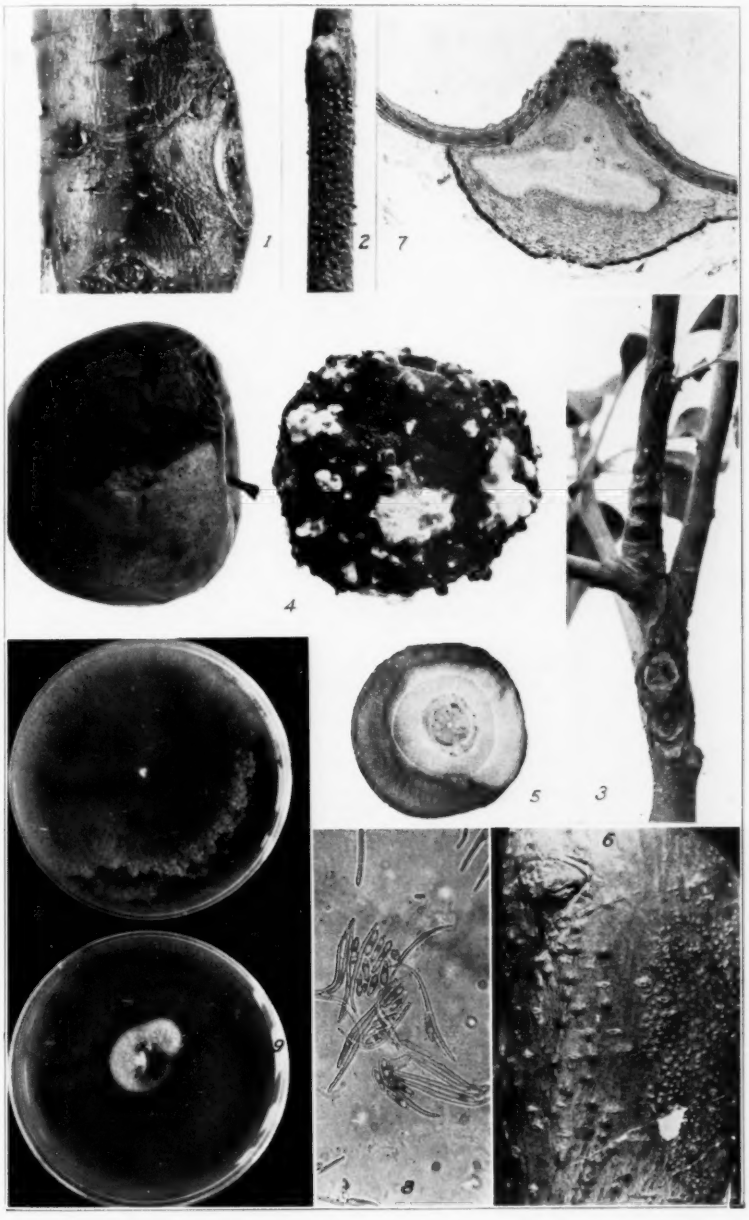

FUSICOCCUM CANKER ON APPLES

THE RELATION OF SOIL MOISTURE TO THE DEVELOPMENT OF COMMON SCAB OF POTATO

G. B. Sanford

The development of a scabby or clean crop of potatoes has almost always been explained on the basis of acidity or alkalinity of the soil, but there are numerous instances where scabby or clean crops of tubers have been harvested apparently regardless as to whether the soil received a treatment of acid or base forming chemicals, or no treatment at all. This indicates that soil reaction, after all, may not be the most important factor in influencing the development of the disease.

Another explanation often given is that the severity of scab may be directly proportional to the number of organisms in the soil, but the correlation does not seem to be consistent.

Extensive field observations and experimental work with common scab in Alberta suggested to the writer that soil moisture often might exert a strong influence on the development of scab. Experiments therefore were begun at the University of Alberta in 1921 and were continued in 1922. During both years the work was carried on under conditions as near those of the field as possible. For instance, plenty of room was allowed to plants, and ordinary untreated soil was used. In 1921 the plants were grown in boxes, 5′ by 3′ by 1′; and in 1922, large tin cans, 22″ in diameter, each containing two plants, gave even better service. The boxes were lined with thick oil cloth to aid in controlling moisture, and water leads were arranged at the corners and bottom edges so that water might be evenly distributed from the bottom as well as from the surface of the soil. A dark organic sandy loam soil, common in Alberta, was used in the experiments. It had produced scabby crops the three preceding years and evidently was heavily infested with *Actinomycetes scabies* (Thax.) Güssow. No inoculum was added. In 1922 a part of this soil was thoroughly mixed with surface soil from the University Experimental Plots which had grown one moderately scabby potato crop.

In order to get a greater temperature range (1921), one section was placed in the greenhouse where the plants grew to maturity under high temperatures during the months of July and August. The other section, a duplicate of that in the greenhouse, was arranged at the same time in the field where the soil boxes were neatly fitted into carefully dug trenches. This arrangement allowed the surface of each box to be

level with the ground so that approximately field temperature might be obtained in the soil. As it was impossible to control temperature under these conditions, the best that could be done was to take daily temperature readings at a depth of 4 inches.

Three series were run: dry, medium, and moist. On an air dry basis these represented a moisture content of about 12, 18 and 28 per cent respectively. The dry soil held too little moisture to produce a good crop, the medium was considered optimum, and the moist soil contained too much to permit normal growth of the plants. In 1922 5 series were tried (A, B, C, D, E). On an oven dry basis, the percentage moisture content of each series was: A—8, B—14, C—22, D—29, and E—34.

FIG. 1. Tubers from dry, medium, and moist soils in 1921. (Right to left.) Upper row grown in greenhouse; lower row grown in field, section of experiment.

The moisture content of A was so low that no tubers were produced; B allowed a fair growth of plant and tubers; C was better than normal field conditions; and both D and E might be considered too moist for good cultural conditions. The moisture content was kept nearly constant by daily weighings in 1922, but in 1921 water was applied according to frequent soil moisture determinations.

1921 RESULTS

The relative amount of scab produced in the dry, medium, and moist soils is shown in figure 1. Badly scabbed tubers were produced both in the dry soil and in the medium, but the potatoes in the moist soil were practically clean. Scab developed exceptionally well in the field where the soil temperatures ranged from 14.5° C. to 19° C. These figures indicate that soil temperatures in Alberta are not low enough to prevent the development of scab.

1922 RESULTS

The 1922 findings are similar to those of 1921. Figure 2 shows, in duplicate, the relative amount of scab produced in each series, excepting A, in which no tubers were formed because of insufficient moisture. In all cases the worst side of the potato is represented. Actual counts of scab spots are given in table 1.

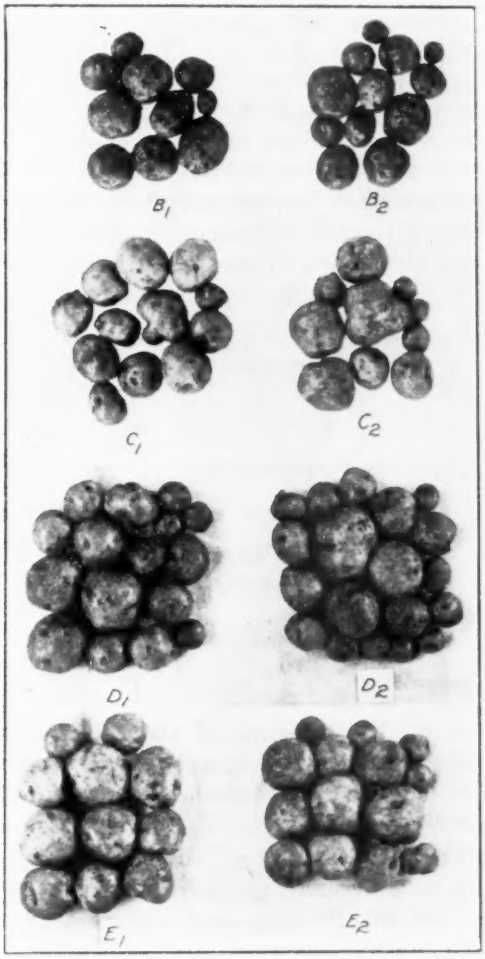

FIG. 2. Duplicate soil moistures of B, C, D and E, showing the effect on scab development in 1922.

TABLE 1—*The effect of different percentages of soil moisture on the development of scab.*

Percentage Moisture	Soil	Large (spots)	Small (spots)	Deep	Total
14	B_1	26	448	10	474
	B_2	83	558	27	641
22	C_1	7	4		11
	C_2	7	4	3	11
29	D_1	1	0		1
	D_2	6	13		19
34	E_1	2	10		12
	E_2	2	8		10

From the figures of table 1, it is evident that the soil contained an abundance of the scab organism and that moisture appears to have controlled, in some manner, the development of scab on the tuber.

Since the amount of scab has generally been attributed to the basic or acidic condition of the soil, hydrogen-ion determinations were made at intervals during the season by means of Leeds-Northrup type "K" potentiometer. The results are given in table 2.

TABLE 2—*The hydrogen-ion concentrations at different dates in soil containing different amounts of moisture.*

Percentage Moisture	Soil	July 28	Aug. 23	Sept. 7	Sept. 17
8	A	7.7	6.1	6.6	6.8
	A	7.7			
14	B	7.7	6.1	6.8	7.1
	B	7.7			
22	C	7.7	6.7	6.9	7.2
	C	7.7			
29	D	7.6	6.9	7.0	7.2
	D	7.7			
34	E	7.7	7.1	7.1	7.2
	E	7.6			

The experiment was started June 10 and tubers formed about July 25 and grew until September 17. It will be seen from table 2 that the pH values in the different soils were nearly the same on July 28; on August 23 the soils were slightly acid, while on September 7 and 17 there was a return to neutrality or slight alkalinity. These figures indicate that dry soils actually are more acid than moist soils under these conditions, and that hydrogen-ion concentration increased as the tubers grew. Apparently moisture, not acidity, was the controlling factor since the dry soil produced the scabby tubers and the more alkaline soil nearly scab-free potatoes.

An experiment was made to ascertain at which stage in the development of the tuber moisture exerts the greatest influence on the development of scab. While results were not entirely conclusive, it was clearly evident that if the soil is moist for a short time after the tubers are set they will not become scabby even after the soil becomes dry later in the season. This is shown clearly in table 3. The potatoes were planted in soil containing about 34 per cent moisture in large cans on June 10. Two cans were run in each series. The soil was all kept moist until June 26 when the soil in the first series was permitted to dry until a water content of 14 per cent was reached. Ten days later the next of the series was dried, and so on until August 25 when all had been dried. Results given in table 3.

FIG. 3. Tubers from the dry soil which became accidently wet during early tuber growth.

TABLE 3—*Scab development in relation to soil moisture at different periods of tuber growth.*

Soil	Date dried	Number of infections
1	June 26	111
2	July 6	312
3	July 16	220
4	July 26	3
5	July 31	46
6	August 5	9
7	August 15	0
8	August 25	4

Relative to moisture and the critical period for susceptibility, an interesting accident in 1921 seems worthy of mention. During the early development of the tubers, as noted at the time, a sudden down-

pour of rain choked the drain provided, and the water ran under the canvas shelter and into both ends of one of the dry soil boxes completely soaking the ground at the ends. Five days later this occurred again. Both times the moisture did not reach the middle hill to any extent. The soil became dry again and at harvest the end hills were surprisingly free from scab, while the middle hill was very scabby. Figure 3 shows the hills as they came from the soil.

SUMMARY

A study of the effect of soil factors on the development of common scab of potato has been made for two years at the Department of Field Husbandry, University of Alberta. The following conclusions seem justified.

Moisture appears to be directly or indirectly the main soil factor controlling the development of potato scab in the type of soil used.

Abundant scab developed in very dry soils, while soils sufficiently moist produced almost clean tubers.

The hydrogen-ion concentration of dry soils, which grew scabby potatoes, was slightly greater than that of the moist soil throughout the season. Scab developed abundantly in a hydrogen-ion concentration of about a pH 6 to 7.

There seems to be a critical period for susceptibility in the growth of the tuber, after which very little scab infection takes place.

A count of the Actinomyces in the soil used, and in others, shows that the organisms are very abundant in Alberta soils.

The study of this problem is being continued in the Division of Plant Pathology, University of Minnesota.

UNIVERSITY OF ALBERTA.

AN OUTBREAK OF HOPPER BURN IN VERMONT

B. F. Lutman

With One Figure in the Text

In spite of a very cool and rainy summer, leaf hoppers have appeared in considerable numbers on the potato plants at Burlington, Vermont, and have induced the very characteristic appearance on them described by Ball (1) in 1918 for the middle-west region of this country. The burns were first noted about August 15 on some Green Mountain plants brought into the laboratory for another purpose. The very cool season has prevented much tip burn of the physiological type so that an opportunity has been given this summer to see practically pure "hopper burn." The potato foliage does not seem to have attained the dark green color so characteristic of it, and these yellow-green leaves and plants have died early without the wilting and gradual advance during hot brilliant days which the author has described in other papers (3, 4). A study of the leaves cleared according to the alcohol-potassium hydroxid-glycerin method (4) has shown that the water pores and the tissues surrounding the water chambers are not brown and dead as was evident according to the observations of last summer but are apparently functioning normally. A few exceptions were apparent under the water pores at the extreme points of some of the leaflets where this apical portion had apparently succumbed to drought, but in general the marginal tissues seemed to be healthy.

Some leaf hoppers were noted during July, but during early August they became so numerous that a few of the young hoppers were found on every plant. The hopper burn was not seen, however, until a little later, when a few rather warm days with a fair amount of sunshine brought it to notice. The hopper burn has been so carefully described by Ball that it is hardly necessary to restate the symptoms here, but in view of the fact that the author has worked with the other phase of the disease, it may be worth while to record the advance in death of parts of the leaves as they appear to a plant pathologist.

1. The most striking difference is first noted in the portions of the leaf involved. The veins and their adjacent tissues become brown to the unaided eye in a V-shaped wedge of diseased tissue. It will be discovered that the browning extends much further along the fine veinlets if the leaflet is cleared and examined under the low power of the compound

microscope, but it seems not to extend beyond the veins themselves. The sieve-tubes and companion cells of these veinlets are brown but along the larger veins, the long parenchyma cells which enclose them seem to be dead as is often the case with the tissue of the leaf itself. The striking point, however, to a student of physiological tip burn is that the vascular system leading from the mid-rib is the centre of the disturbance. The death is from the centre of the leaf outward while, in physiological tip burn, the reverse is true.

2. The second most striking difference lies in the portion of the leaflets involved. Tip burn would be a misnomer for hopper burn as any portion of the leaf might be involved and destroyed by the attacks of the insects and the tip is not more susceptible than the basal portions. In facts the insect may attack and destroy the main vein of the leaflet leading to the tip and the tip still remain green because the water continues to flow into it through the marginal plexuses described by the author in a previous paper. Figure 1, D illustrates this point. The mid-rib had collapsed and was brown as was also the surrounding tissue for an area of about a half a centimetre, but the extreme tip was unaffected. The same thing is shown in figure 1, A where the side of a leaflet died but the tip did not. Such a condition would not occur in ordinary tip burn of the physiological type.

It is very evident that in many instances it is almost impossible to distinguish the two forms of injury since they occur simultaneously. A careful examination of a number of the leaflets will make it fairly clear as to the factors involved if the two differences noted above are kept in mind. The entomologists have in some cases assumed that only one type can occur.

3. The seriousness of hopper burn as compared to physiological tip burn depends on the character of the weather during the summer in which the study is made. During the summer of 1921, when many plants in Vermont fields were almost denuded of their foliage by tip burn in a few weeks, the leaf hoppers must have played a very minor role, but during the summer of 1922, the bulk of the injury was of insect origin. There seems to be no question that the leafhopper can kill the leaflets even in cages and under greenhouse conditions where the sunlight is so weak that it will only rarely bring about a scald or burning in a few leaflets. In a hot, dry period, however, the sunlight may remove 30 to 50 per cent of the foliage in a week by causing extreme plasmolysis and pronounced wilting of the tips and margins. It would seem, therefore, to be a problem for the plant pathologists each year in the potato growing regions to note the advance of tip burn and to collaborate with the entomologists in determining the relative amount of the two types of injury.

Has the leaf hopper spread from the western states eastward in a similar manner to the Colorado potato beetle? How does the leaf hopper work on the leaflets?

The spread of the leaf hoppers, if it occurred, is probably very recent —a fact which should be ascertained before the evidence is lost. A small

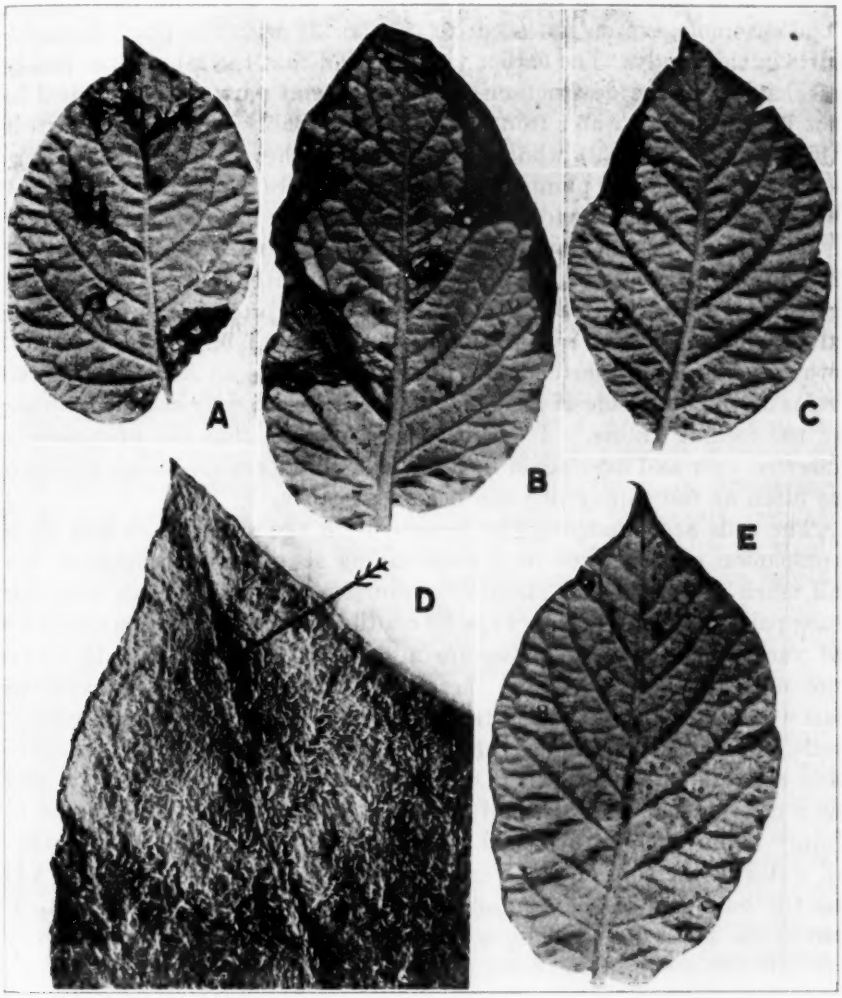

FIG. 1. Characteristic hopper burn. Its early stages are shown in leaves A, B, and C. The mid-rib of leaf D (much magnified) is collapsed, the surrounding tissue being brown and dead. The tip is still green except at the extreme point. Leaf E seems to be in the early stages of physiological tip-burn, especially on the left side.

inconspicuous insect of this type could gradually make its way eastward without being noticed. The early descriptions of tip burn undoubtedly dealt only with the physiological form and the introduction of the hopper has injected quite a new factor into the problem.

The means whereby such small insects bring about such an almost incredible amount of injury in so short a time should be determined. The entomologists do not seem to collaborate with the plant pathologists in this study. The earlier views of Ball that the injury was partly mechanical in the destruction of the veins and partly physiological in the withdrawal of water from the cells is probably more nearly correct than that of Eyer (2) who would have us believe that some toxin is exuded as the hopper pumps the juice from the leaves. The experiments of this investigator would seem to indicate some such substance but it is doubtful if such an assumption is really necessary. A careful study of a number of leaves cleared in glycerine frequently failed to reveal the exact spot where the leaf was punctured by the proboscis of the hopper although the general region of destruction could be seen. Ball and others have noted the tendency of the hoppers to sit and suck on the veins on the underside of the leaf. A more careful study should be made of the feeding habits. It seems very probable, that the proboscis is inserted over and over again into the leaf, the operation being repeated as often as the supply of juice becomes scanty.

The cells accompanying the vessels, both the sieve tubes and their companion cells, as well as a surrounding sheath of parenchyma, are all much elongated and plasmolyse much more readily than even the long palisade cells. This fact can be readily confirmed by using solutions of various strengths of potassium nitrate on leaf sections. It seems not unreasonable to assume, therefore, that the leaf hopper removes the water from the tubes and from the adjacent sieve tubes, companion cells, and elongated parenchyma to such a degree that they plasmolyse and collapse to a point where they cannot regain their turgidity, and as a consequence they die and become brown in color. The extent of injury about such an attacked region would depend upon the amount of water in the soil, on the warmth and brilliance of the sunshine and on the humidity of the atmosphere. This explanation would seem to cover the faces observed by a study of the leaves themselves and to obviate the assumption of toxic injection.

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POTATO SCAB IN NEW LAND

B. F. LUTMAN

Some years ago, Mr. G. C. Cunningham, then associate Plant Pathologist of the Vermont Agricultural Experiment Station, suggested to the writer that a study of the occurrence of scabby potatoes on new land that had not been previously cropped might throw some light on the suspected general distribution even in new soil of the scab producing organism. Mr. Cunningham left the Vermont Station before any experimental work was done in this connection but the author has carried out field trials during the past six years with a view of throwing light on this subject.

There is very little literature on the subject of the occurrence of any disease in absolutely new soil, apparently free in every way from the organisms associated with it. Plant pathologists seem so obsessed by the narrowest possible interpretation of the germ theory of disease that even the suggestion that many of the parasitic organisms are only common saprophytic ones whose mode of life has been altered, would be regarded as rank heresy. Every specific disease has its own specific parasite associated with it. Jones and Edson[1] at the Vermont Station in 1901 unintentionally have shown that potatoes may be scabby even though raised on new land. These investigators attempted to find land that contained no scab producing organisms in order to test the efficacy of seed treatment. Absolutely new land that had been recently cleared of pine and had not been previously cropped was planted with seed that had been soaked for one and a half to two hours in corrosive sublimate solution, one part in a thousand of water, or in formaldehyde, one part in two hundred and forty of water. It is generally assumed that this treatment is sufficient to kill all fungi of the Actinomyces type and laboratory tests confirm this assumption. In spite, however, of such treatment, the rows containing seed pieces soaked in the corrosive sublimate solution produced 2.75 to 5.9 per cent and those soaked in

[1] Jones, L. R. and A. W. Edson. Potato scab experiments of 1901. Vermont Agric. Exp. Sta. 14th Ann. Rpt., 1900–01: 231–235. 1901.

formaldehyde solution 1.50 to 10.66 per cent of scabby tubers. The only possible assumption of error for those who believe that the parasites are always introduced into virgin soil by scabby seed, is in the unreliability of the disinfection methods.

In 1916, four small plots of formaldehyde disinfected potatoes were planted in small spots, open to the sky, in the "College Woods," a white pine growth at least fifty years old and uncleared in the present generation.

TABLE 1—*Showing the percentage of scab and Rhizoctonia infected potatoes in four small plots, in soil which had not been cultivated for at least 50 years.*

	Disease	Tubers free from	Slightly scabbed tubers	Badly scabbed tubers	Per cent clean	Per cent slightly scabbed	Per cent badly scabbed
Plot 1	Common scab	10	3	0	77	23	0
13 tubers[1]	Rhizoctonia	13	0	0	100	0	0
Plot 2	Common scab	9	6	0	60	40	0
15 tubers[2]	Rhizoctonia	0	6	9	0	40	60
Plot 3	Common scab	56	36	18	51	33	16
110 tubers[3]	Rhizoctonia	76	22	12	69	20	11
Plot 4	Common scab	11	16	1	39	57	
38 tubers[4]	Rhizoctonia	0	16	12	0	57	43

[1] Four hills in sandy, dry soil on a hill side.
[2] Four hills in very dry, sandy soil on top of a hill.
[3] Fifteen hills in sandy loam.
[4] Six hills in sandy loam with much forest humus; in a shady situation; yield small.

The work was discontinued during 1917 and 1918, owing to lack of assistance, but experimental work was again attempted in 1919, when about an eighth of an acre of clean, disinfected Green Mountain potatoes were planted in a piece of land cleared of pine during the preceding winter. No commercial fertilizer was put in the hills. Many of the pine roots and stumps were still in the plot. The soil was very sandy but with an abundance of forest humus. The plot was in a very low lying situation and in the early spring the water table was not over a foot from the surface of the ground. An examination of several bushels of the tubers produced showed between one half and one per cent of

them with typical deep scab spots. In the majority of cases these lesions were single but occasionally an entire end or side of a tuber was covered by the brown corky growth.

In 1920, part of the same land was planted with clean disinfected Irish Cobblers, and some rows were placed in a new strip that had been cleared of pine during the winter. A commercial potato fertilizer was added to the hills. The count showed 93 per cent of clean tubers and 7 per cent of scabby tubers on the land used the year before and 97 per cent of clean and 3 per cent of scabby on the potatoes from the virgin soil. The new land was a little lower and wetter than the old portion.

In 1921, the same land was again employed for these experiments. A strain of Green Mountain seed, clean, but also disinfected with formaldehyde was planted and commercial fertilizer was added to each hill. When the plants were dead,—Sept. nineteen,— and the rows dug, it soon became apparent that the amount of scab in various parts of the long narrow plot varied greatly so the results were compiled in three parts.

	Clean	Slightly scabbed tubers	Badly scabbed tubers
	per cent	per cent	per cent
South end	40	43.	17.
Middle	87.	12.	1.0
North end	83.	15.	2.
Average for entire plot	71.	22.	7.

The two ends of the plot were apparently the same soil and had received identical treatment. Poured agar plates showed an abundance of organisms of the *Actinomyces chromogenus* type present in the north end.

The experiments made in 1919, 1920, and 1921 illustrate the rapid increase in scabby potatoes on land continuously cropped with potatoes. The occasional scabbed tuber of 1919 increased to 60 per cent of the crop at the south end of the plot in 1921, even when all precautions were taken against the introduction of parasitic strains of the seed tubers or in the manure. It would hardly seem possible that the few lesions found in 1920 would so infect the soil that almost every tuber in growing would come in contact with a bit of parasitic mycelium unless the roots of the potato were covered with it. It would seem more reasonable to suppose that the particular methods used in potato tilth give the organisms of the scab type a chance to come to the front in the destruction of the cellulose in the soil humus and that parasitism is entirely secondary.

The same plot was again planted in 1922, but the very rainy June (9.92 inches) caused every seed piece to rot. Four plots were also planted in another region in small openings in near by pine woods. This land had never been under cultivation and the plots were surrounded by pine trees 30 to 50 years of age. The soil was light and sandy except in plot II (which was on low ground and a rather heavy clay). A commercial potato fertilizer was used. The plants were at a disadvantage from lack of light and the yield and the tubers were small. The following tabulation of the yields will show the rather high percentage of infection:—

	Number of hills	Tubers showing Rhizoctonia	Tubers clean	Tubers slightly scabby	Tubers badly scabby	Per cent clean	Per cent slightly scabby	Per cent badly scabby
I	16	4	63	24	6	68	26	6
II	4	3	17	2	4	74	17	9
III	9	0	7	3	1	70	30	10
IV	20	5	38	11	0	78	22	0

The scabs obtained on these tubers were typical and in some cases covered almost half the entire surface. The presence of Rhizoctonia sclerotia is also of interest and shows that new land is not necessarily clean land.

SUMMARY

Potatoes grown on land never cultivated will often develop typical common scab lesions and Rhizoctonia sclerotia, even if the seed tubers are disinfected and only commercial fertilizers are used.

DOTHICHIZA CANKER ON NORWAY POPLAR

FREDA DETMERS

WITH PLATE XIII

Poplar canker caused by *Dothichiza populea* Sacc. and Briard, has been reported in the United States (2) and Canada (3) on several species of poplar, notably *Populus nigra* and *Populus deltoides*. The latter may also cover the variety *P. monilifera* which according to Bailey (3) is the northern cottonwood. The author knows of no publication reporting this disease on the Norway poplar, *Populus eugenei* Simon-Louis. She wishes, therefore, to record the occurrence of Dothichiza canker on *Populus eugenei* in Ohio.

HISTORICAL SKETCH

In the spring of 1917, the Mead Pulp and Paper Company of Chillicothe, Ohio, set out 1200 Norway poplars in the bottom lands of Paint Creek, a tributary to the Scioto River. On May 5 of that year, Mr. Bearce, forester to the company, reported a bark disease of these poplars to the Department of Botany of the Ohio Agricultural Experiment Station. No definite conclusion was reached as to the identity of the disease at that time, but fear was expressed that it might be due to *Dothichiza populea*. During 1921 the attention of the department was again called to the case and a personal visit was made. Careful examination of abundant material has established the identity of the causal organism to be *Dothichiza populea*. This diagnosis has been corroborated by cultures, and was verified by Dr. George G. Hedgcock to whom I sent fresh material. In 1921, the company had five blocks of Norway poplars ranging in age from one to six years all severely infected. The disease has been so destructive that the company has decided to abandon the Norway poplar and during the past winter blocks of one and three and four year old trees have been dug out and burned. In the six year old block of trees the disease has progressed less rapidly during the past season. It is possible that these trees may recover sufficiently to be worth saving.

FIELD OBSERVATIONS

Infection takes place at the nodes. The discolored area may be immediately below the leaf scar, in the axil of the bud, or on either side of the bud in proximity to the stipular scars. The bud itself is not attacked. Cankers form at any node on two year old wood. The lowest

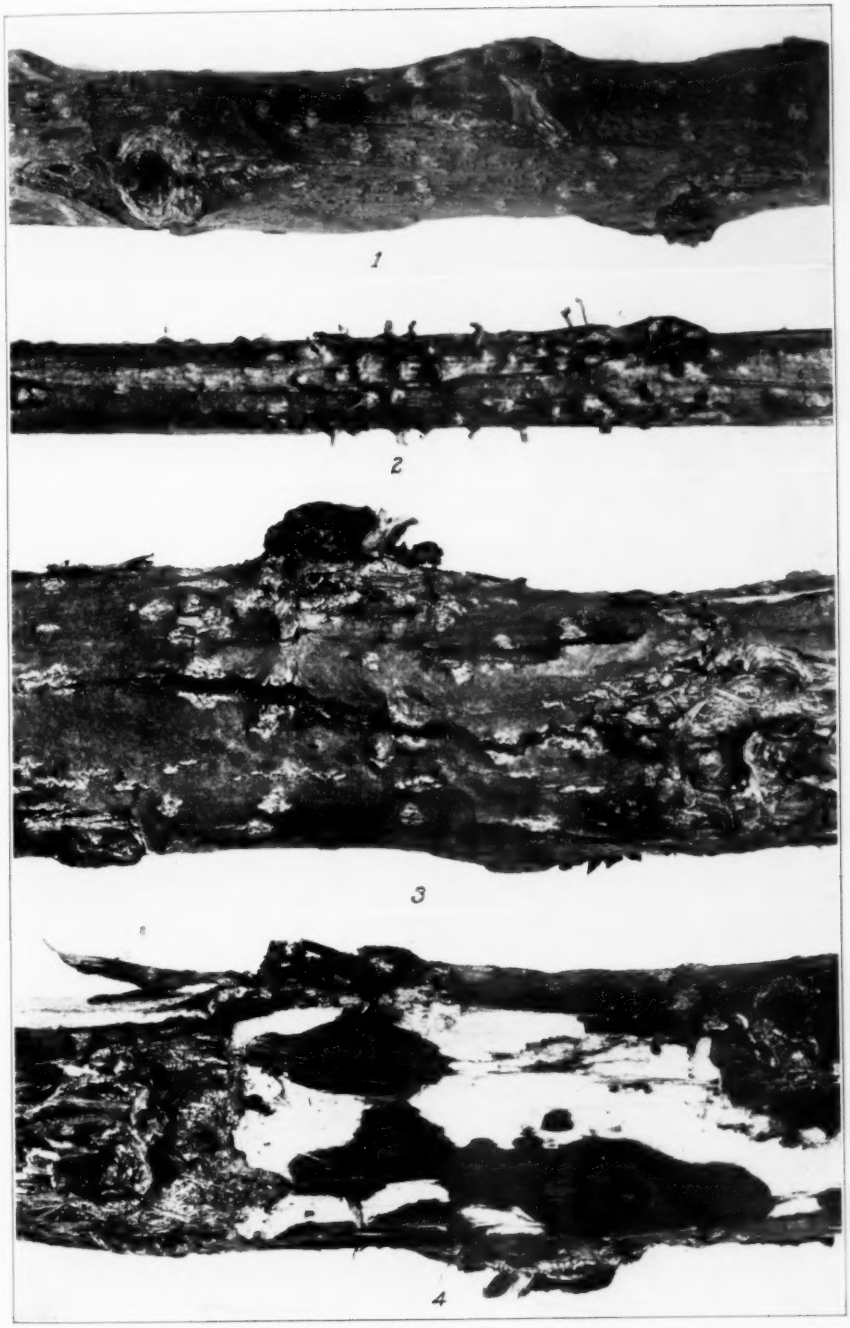
found was on the trunk of a four year old tree, three inches from the ground. The annual spread of infection has generally been slower than the growth of the trees and has not extended beyond one year old wood; however, in severely diseased young trees the current-year's growth was also invaded. A large branch of one of these trees was surrounded at its base by a pronounced canker. The branch had thirty-two nodes, (Pl. XIII, 2) of which the fifth, sixth, ninth, eleventh, sixteenth and eighteenth nodes were infected. The relative age and severity of attack indicated that the trend of infection had been upward from the lower to the higher nodes. Numerous pycnidia were scattered (Pl. XIII, 1) over infected areas on the young branches, and from them the characteristic broad rather short spore threads emerged. Cankers on older branches (Pl. XIII, 3) are rough, the bark becomes cracked exposing in severe cases the wood beneath. The sap wood is invaded (Pl. XIII, 4) becomng deep shining brown as shown in the illustration. Lateral branches from infected areas are killed. The dead lateral branches are a striking feature of the presence of the disease. Cankers spread laterally, finally coalesce and girdle the main trunk. As the spread of invasion is from below upward the upper buds remain healthy and often make a vigorous growth of ten feet in one season. This rapid growth is characteristic of the Norway poplar.

THE NORWAY POPLAR

A brief statement of the identity of the tree known to nurserymen as the Norway Poplar or "Sudden Sawlog" may not be amiss as it seems to be but little known. I am indebted to Dr. George B. Sudworth (4), Dendrologist, United States Forest Service, for the information:—that the tree is a hybrid between a European-grown form of our common eastern cottonwood *Populus deltoides* and the European black poplar, *P. nigra*. This hybrid was described and named in Europe many years ago as *Populus eugenei*. Dr. Sudworth adds:—"Another name for it is possibly *Populus robusta*, which first appeared in French literature, this form having originated in a French nursery and is believed to be from the same parentage as *Populus eugenei*. Doubtless the French form was grown in Norway where the name Norway Poplar was applied."

Bailey (1) says of *Populus eugenei* Simon-Louis, "This interesting and valuable, rapidly growing poplar was found in 1832 as a chance seedling in the Simon-Louis nursery, near Metz, France; it is supposed to be a hybrid between Lombardy poplar (male) and *P. regenerata* (female)."

C. S. Harrison, a nurseryman of Falling Water, Nebraska, is accredited with having introduced the tree into America.



DOTHICHIZA CANKER ON NORWAY POPLAR.

The tree is similar to *Populus nigra* in its strict habit of growth, narrow crown, dark bark and failure to clean up the trunk through self pruning. The shape of leaf blade and bud are similar to that of *P. deltoides*. It grows much more rapidly than either parent and because of its rapid growth it is deemed of value as a source of wood pulp, for it can be cut several years earlier than other poplars. The poplars stand first among the hard woods suitable for wood pulp; and because of its rapid growth the Norway is preferred to other species of poplars, consequently the extreme susceptibility of this tree to Dothichiza canker and the virulence of the disease is a blow to the wood pulp industry in Ohio.

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(1) BAILEY, L. H. The Standard Cyclopedia of Horticulture. 6 v. New York, London. 1914.
(2) HEDGCOCK, G. G. and N. R. HUNT. *Dothichiza populea* in the United States. Mycologia **8**: 300–308. *Pl. 194–195.* 1916. Literature cited, p. 308.
(3) Moss, E. H. Observations on two poplar cankers in Ontario. Phytopathology **12**: 425–427. 1922. Literature cited, p. 427.
(4) SUDWORTH, GEORGE B. Personal letter. Dec. 29, 1921.

A MELIOLA DISEASE OF CACAO

F. L. STEVENS AND RUTH I. DOWELL

WITH THREE FIGURES IN THE TEXT

During an inspection of cacao plantations at Coverden, British Guiana, for pod rot and witches broom a leaf-spot disease evidently due to Meliola was seen in considerable abundance and collected. The disease as manifest in this plantation cannot be considered as serious though it is conceivable that under especially favorable conditions it might become so.

Of the numerous species of Meliola those that cause appreciable killing of tissue are in small minority. Meliola was long considered to be merely a superficial fungus; then it was demonstrated that it sends numerous haustoria into the epidermal cells, and usually without apparent effect on the host. Now, however, several species of the genus are known to produce dead spots coincident, or nearly so, in size with the superficial colony, the spots so produced showing as dead areas from

both sides of the leaf. Such is the case in the present instance and spots of dead leaf tissue 3 to 10 mm. in diameter are produced. The Meliola proves to be a new species and is described as follows:

Meliola guianensis n. sp. (Figs. 1, 2 and 3A to 3D.)

Fungus hypophyllous. Colonies 3–10 mm. in diameter, nearly circular; the spots visible from the opposite side of the leaf.

Perithecia about 280 μ in diameter, somewhat warty. Setae dark, spiral, echinulate on the upper one-third to one-half of length, about 86 μ long × 7 μ thick. Asci evanescent. Spores 4-septate, 54 × 19 μ, dark. Mycelium slightly sinuous, branches opposite, sometimes alternate. Capitate hyphopodia alternate, rarely opposite. Mucronate hyphopodia opposite and alternate. Mycelial setae absent.

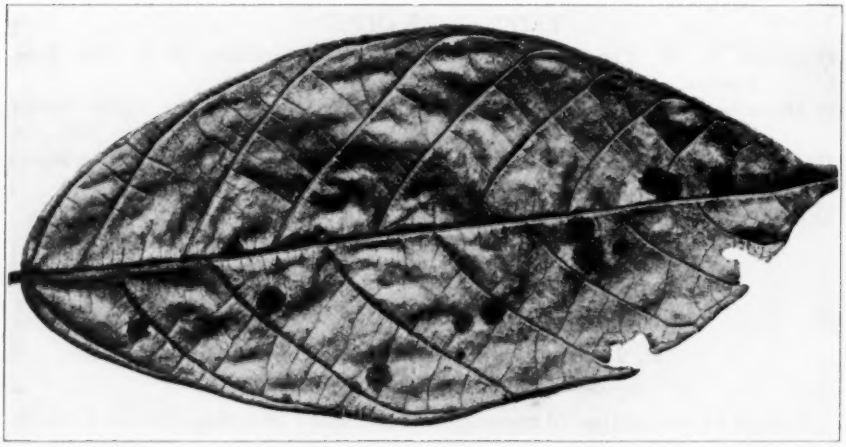

FIG. 1. Leaf of *Theabroma cacao* showing distribution of colonies of *M. guianensis* × 1; reduced 1/3.

Group number 3301.5231.

On *Theabroma cacao*. British Guiana; Coverden, August 4, 1922, number 974.

The group number given above is based on the system of Beeli[1]. The species falls within a small group of the genus characterized by the possession of 4-septate spores, perithecia with setae, no mycelial setae and alternate hyphopodia. There were only seven such species previously known and with only one of these, viz. *M. tortuosa* Wint., is it in

[1] Beeli, M. Note sur le Genre Meliola Fr. Bull. Jard. Bot. Bruxelles **7**: 91. 1920.

at all close agreement. From this species, however, it differs markedly in that the perithecial setae in the present species are distinctly echinulate in their distal portion, (Fig. 3A and E); also the perithecia (about 280 μ in diameter) and spores (54 × 19 μ) are larger than those of *M. tortuosa* which are respectively 160–190 μ in diameter and 31 to 36 × 12 μ (Fig. 3B and F); the setae and mycelium are opaque and darker than those of *M. tortuosa;* and the mycelium is somewhat larger and less sinuous (Fig. 3C, D and G).

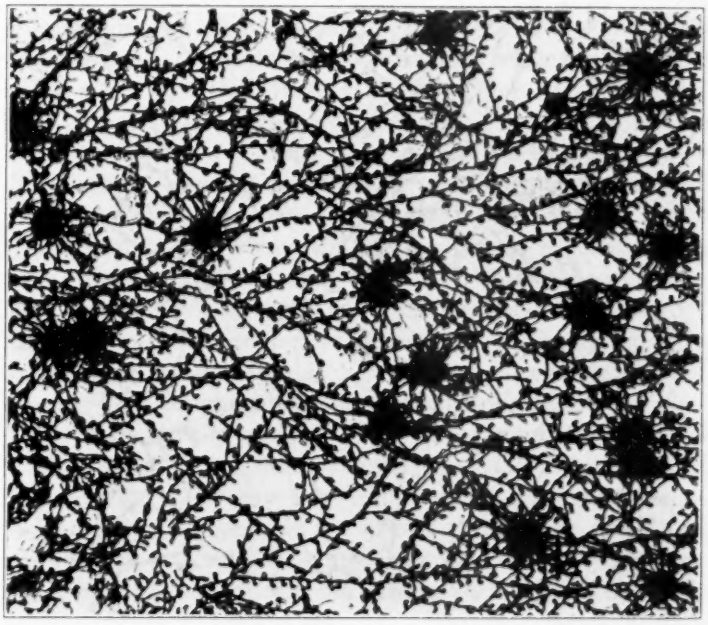

FIG. 2. Photomicrograph of *Meliola guianensis*, portion of colony showing mycelium hyphopodia and perithecia.

Meliolinopsis theabromae Beeli (syn. *Meliola theabromae* F.C. v. Fab.) having a spore length of only 10 μ and with 8-spored asci is very different.

The Meliola was overgrown in some instances by a Helminthosporium, in others by a Nectria, the former rendering the colony unusually black and the latter making it white, thickly strewn with the pink perithecia. The Helminthosporium is new and is described as follows:

Helminthosporium guianensis n.sp. (Fig. 3H.)

Mycelium fine (1.5 μ) pale straw-colored, conidiophores thicker (3 μ), pale brown, occasionally branching, 68 μ long. Conidia 3-septate, 18–21 × 3–7 μ, thicker in the middle and tapering toward both ends.

On *Meliola guianensis* Stev. & Dow. on *Theabroma cacao*. British Guiana, Coverden, August 4, 1922, number 974.

The Nectria appears to be *N. portoricensis* Stev., though it differs in that it does not coat the Meliola mycelium with a white mycelium. The perithecia are scattered throughout the colony and are pale flesh color rather than red; and the spores are hyaline.

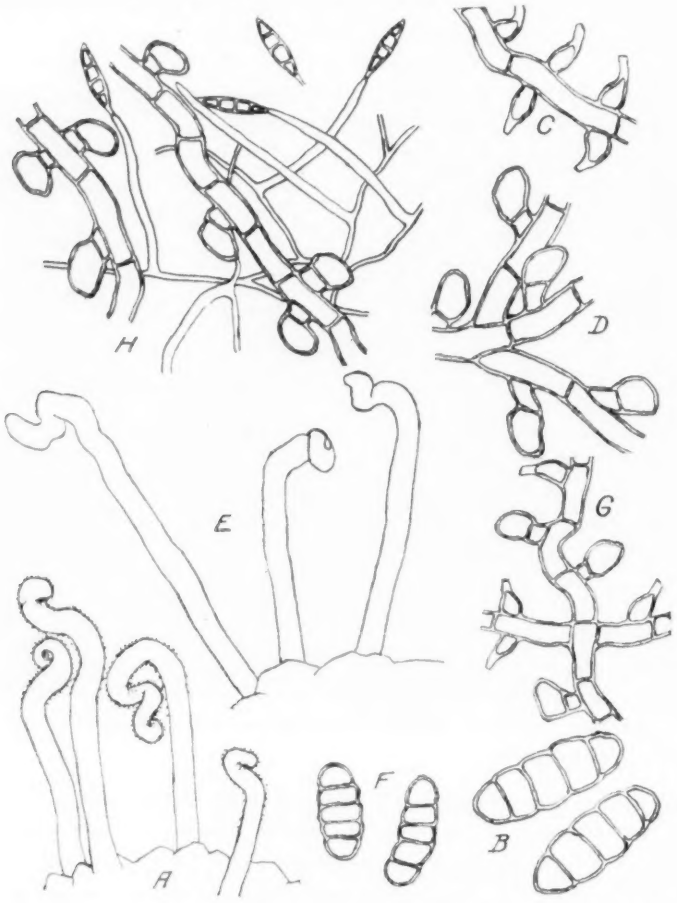

FIG. 3. (Drawn to a high power.) A, *M. guianensis*, surface of perithecium and echinulation of setae; B, *M. guianensis*, ascospores; C, *M. guianensis*, mucronate hyphopodia; D, capitate hyphopodia; E, *M. tortuosa*, surface of perithecium and setae; F, *M. tortuosa*, ascospores; G, *M. tortuosa*, mycelium showing mucronate and capitate hyphopodia; H, *Helminthosporium guianensis*, showing mycelium, conidiophores and conidia, and mycelium of *M. guianensis*.

THE HOT WATER TREATMENT OF CABBAGE SEED

J. C. WALKER

In a former paper[1] the writer has shown that the cabbage black-leg organism, *Phoma lingam* (Tode) Desm., can not be completely eradicated from internally infected seed, by any method tried, without more or less reduction in amount of seed germination. Inasmuch as different lots of seed vary widely as to the amount of injury sustained from stronger treatments, a moderate but safe formula was recommended for general use (mercuric chloride solution 1 : 1000 for 30 minutes). While the above limitations of seed treatment point to the ultimate control of black-leg through the production of disease-free seed, the fact still remains that cases arise from time to time in which complete disinfection is essential even at the expense of a moderate reduction in germination. This is especially true in the case of infected but otherwise very valuable stock seeds from which it is advisable to eradicate the fungus before they are planted for purposes of multiplication. It is a problem of primary interest to the commercial seed grower as well as to the experimenter in selection and breeding. In our own experience in selecting yellows-resistant strains of cabbage we have found it necessary to devise a method for complete disinfection of small lots of pedigreed seeds which had become infected by *Phoma lingam*. Several commercial seedsmen have also recently sought advice on the same question.

The procedure already outlined in the paper mentioned, was therefore continued in order to determine the most satisfactory method for complete disinfection. The dry heat and formaldehyde treatments being obviously out of the question the effects of stronger treatments with mercuric chloride and with hot water were studied further. It was soon decided, as may be judged from the data in Table I, that mercuric chloride was unsatisfactory for the purpose. Hot water gave more promise. It will be seen that complete disinfection was nearly reached with 15 minutes' exposure at 50° C. and was completely attained with 30 minutes' exposure at the same temperature. Moreover, the increase in temperature to 55° C. did not shorten the period necessary for complete disinfection.

Supplementary field tests with treated lots of infected seed under conditions very favorable for black-leg development, showed the mercuric-chloride treatment to be unsatisfactory and the hot water at 50° C. for 15 minutes insufficient. The longer hot water treatment (50° C., 30 minutes) yielded practically perfect control.

[1] Walker, J. C. Seed treatment and rainfall in relation to the control of cabbage black-leg. U. S. Dept. Agric. Bull. 1029. *27 p.* 1922.

TABLE 1—*Effect of hot water and mercuric chloride treatments upon the viability of Phoma lingam in infected cabbage seeds.*

Number of seed lot		1		2		3	
Treatment		Number of seeds used	Seeds with viable fungus after treatment (per cent)	Number of seeds used	Seeds with viable fungus after treatment (per cent)	Number of seeds used	Seeds with viable fungus after treatment (per cent)
Control		117	60	29	52	24	67
Mercuric chloride 1 : 500	30 min.	31	65	—	—	10	50
	60 "	30	47	—	—	22	64
	120 "	30	30	—	—	25	4
Hot water	50° C. 15 min.	163	0.6	19	0	—	—
	50° C. 30 "	141	0	20	0	15	0
	55° C. 15 "	—	—	—	—	35	3
	55° C. 30 "	—	—	—	—	24	0

The effect of these two lengths of exposure at 50° C. was studied with a number of seed samples of known age and origin as well as with several taken at random from a retail seedsman's list. From the data secured (Table 2) it will be seen that as a rule little reduction in germination was experienced with the shorter treatment. With the longer exposure (30 minutes) the reduction was more marked, and as a rule it was more

TABLE 2—*Effect of hot water treatment upon the germination of cabbage seed*

Variety	Approximate age of seed (months)	Percentage germination		
		Control	50° C. 15 min.	50° C. 30 min.
Wisconsin All Seasons	3	92	90	90
Wisconsin Hollander	6	93	86	85
Wisconsin Hollander	6	82	68	67
All Seasons	6	97	91	82
Wisconsin All Seasons	18	69	69	63
Wisconsin Brunswick	18	67	64	50
Wisconsin Hollander	18	65	47	38
Wisconsin All Seasons	30	70	63	47
Sure Head	Age unknown; samples taken at random from retail seedsman's list	89	—	61
All Head Early		81	—	67
Danish Ball Head		85	—	76
Dry Weather		81	—	49
Earliest of All		74	—	31
Early Summer		34	—	13
Late Flat Dutch		38	—	4

pronounced in the older seed. Retarding of germination was usually noticeable in treated lots and it increased roughly in proportion with reduction of percentage of germinating seeds. It is evident from these data that seed of high germination when treated at 50° C. for 30 minutes within the first six months after harvest may be expected to suffer only moderately in reduction of germination. The injury may be expected to increase with the age of the seed at time of treatment. The variability in the results secured with seed lots picked at random is therefore to be expected.

For the special cases already outlined, where complete freedom from the black-leg fungus is urgently needed, the treatment with hot water at 50° C. for 30 minutes is practicable. We have used it satisfactorily for the past two years on seed lots varying in size from a few grams to several pounds. The limitations of the treatment should be recognized, however, and preferably preliminary trials with a few seeds should be made. The variability in injury sustained by seed lots picked at random preclude the recommendation of this treatment for general use.

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BANANA WILT OF THE MANILA HEMP PLANT

H. ATHERTON LEE AND F. B. SERRANO

Manila hemp is regarded among fiber men as unequalled among plant fibers for the manufacture of high grade cordage such as that used on ships and for other marine uses. It is obtained by a stripping process from a plant closely resembling the banana plant in appearance, a member of the same genus, *Musa textilis* Neé. The Manila hemp plant is confined in its distribution to the Philippine Islands and has never to the present time been successfully cultivated commercially in any other country. The Philippine Islands therefore hold a monopoly on the production of the very superior plant fiber, Manila hemp.

A disease of the Manila hemp plant was described in 1915, by Reinking[1] as abaca[2] heart rot and its cause ascribed to bacteria, the identity of

[1] Reinking, O. A. Philippine economic-plant diseases. Philippine Jour. Sci. Sec. A. **13**: 221. 1918.

[2] Abaca is the dialect word in the Philippines for the Manila hemp plant.

which were undetermined. More recently, this disease has increased in seriousness and investigations were requested by commercial growers. The distribution of the disease was first determined and it was found to be destructive only in the provinces of Laguna and Cavite.

Isolation and inoculation studies were undertaken with the expectation of corroborating earlier results as to the cause; bacteria were found in isolation studies to be commonly associated with advanced stages of the disease, although an imperfect fungus was almost as uniformly isolated. As familiarity with the disease became greater it was possible to find less advanced pathological stages and from such earlier stages, a Fusarium was obtained in a very high percentage of cases. Examination of fresh frozen sections and of serial paraffin sections showed with little or no difficulty the presence of fungus hyphae in the early advancing stages of the disease. Isolations were continued repeatedly, in all 1468 isolations being made; after the first four series of isolations, Fusarium began to appear and from that time thereafter appeared in 60.44 per cent of the plantings. Few fungi of other genera appeared in such plantings. The bacteria isolated in the older stages did not appear uniformly although three different forms of colonies on beef agar plates appeared more frequently than others.

The isolation attempts having reached this stage, inoculation experiments were tried. The bacterial species for convenience were termed organisms A, B, and C. Since the bacterial species ascribed as the cause of the disease by Reinking was not described, its identity with any one of these three organisms could not be determined. Inoculation studies have been made with all three of the bacterial species and with the Fusarium. Inoculations were made with needle punctures, through the pseudostem into the central cylinder. Table 1 shows the number of such inoculations and results.

It seemed apparent to us, therefore, that the Fusarium species was a pathogene.

Studies were then taken up to identify this Fusarium species. We had recently isolated *Fusarium cubense* Erw. F. Smith, from banana wilt cases in the Philippines and the hemp plant fungus was being cultured at the same time. Comparisons were naturally made of morphological and cultural characters and it was found impossible to distinguish the two fungi in this way.

In earlier studies the banana wilt fungus inoculated into banana plants caused blackened discolored rhizomes, splitting of the pseudostem and yellowing and dying of the leaves. The same organism inoculated with

TABLE 1—*Showing results of inoculations into the central cylinders of the Manila hemp plant, with various organisms isolated from heart rot cases. Sterile needle punctures used as controls.*

	Number of inoculations	Number of positive infections	Percentage of positive infections
Organism A	20	1	5.00
Organism B	80	8	10.00
Organism C	145	9	6.20
Sterile needle puncture through sterile external surface	70	4	5.71
Hemp Plant Fusarium	199	96	48.24[1]

the same technique into the pseudostems of Manila hemp plants did not cause such lesions and the hemp plant was at the time considered resistant.[2]

Inoculations were made with needle punctures, through the thick pseudostem, into the central cylinder of Manila hemp plants with the banana wilt Fusarium, and with the Manila hemp plant Fusarium. The banana wilt Fusarium gave 65 infections in 115 inoculations, or 56.5 per cent; the Manila hemp Fusarium gave 89 out of 134 attempts or 66.4 per cent.

Since the morphological and physiological characters of the hemp plant pathogene seem to be similar to those of the banana wilt organism, *Fusarium cubense*, the two must be considered for the present at least, as belonging to the same species.

The conclusions moreover are, that *Fusarium cubense* can not produce banana wilt symptoms upon the Manila hemp plant, but if inoculated into the growing central cylinder of the hemp plant by means of the proper technique, it can produce typical heart rot. The interesting situation is developed of a fungus species producing one set of symptoms on one host plant, and an entirely different set of symptoms on another.

Only two banana plants have been inoculated with the Manila hemp Fusarium, but both plants have given banana wilt symptoms, probably

[1] As the technique was improved, positive results were obtained with the hemp plant Fusarium in 89 out of 134 attempts or 66.41 per cent. Failure to obtain 100 per cent positive results possibly may be correlated with the improbability of placing the inoculum, through the thick resistant pseudostem into the susceptible central cylinder tissues in every inoculation attempt.

[2] Lee, H. A. and F. B. Serrano. Banana wilt in the Philippines. Phytopath. **10**: 504–505. 1920.

more promptly and virulently than would *Fusarium cubense* direct from banana wilt. A control puncture remained healthy.

Our knowledge of heart rot of the Manila hemp plant is, therefore, greatly increased since, from the work of Brandes[1] it is known that *Fusarium cubense* is not a strict parasite. It can, however, exist in the soil and infection can take place from that source. The discovery of this fact leads also to an understanding of the heart rot of the hemp plant which may become just as destructive as is the banana wilt in the West Indies.

The most promising means for the control of the disease seems to be with resistant varieties. A more detailed report will appear in the Philippine Journal of Science.

PHILIPPINE BUREAU OF SCIENCE,
PHILIPPINE BUREAU OF AGRICULTURE

[1] Brandes, E. W. Banana wilt. Phytopath. **9**: 339–389. *5 fig., pl. XXI–XXXIV (partly col.)* 1919. Literature cited, p. 388–389.

Errata: February number of Phytopathology, page 99, line 5, instead of "one plant" read "all the descendants of one."

Page 38, article by V. F. Tapke, last line instead of "controls loose smut of wheat reducing yields" read "controls loose smut of wheat without reducing yields".

The April number of Phytopathology was issued April 4, 1923.